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POLLUTION CONTROL OF BLAST FURNACE PLANT GAS SCRUBBERS THROUGH RECIRCULATION

Robert E. Touzalin

Interlake, Incorporated

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After the recycle system started operating, gross contaminant discharge decreased to 1,900 tons per year, and net discharge became a negative quantity.

The construction cost of the unified recirculating system was $1,109,400 for this plant producing about 3,200 tons of hot metal and 3,300 tons of sinter per day. Operating costs are about $285,000 per year higher than the costs of operating the old "once-through" water system. Elimination of dredging costs, and increased iron recovery produce savings of about $10,000 per year, so the net increase in plant operating costs is about $275,000 per year, or $.0001 per gallon of throughput.

*Chemical Control, *Contaminants, *Flocculation, *Recirculated Water, *Water Clarification, Acidity, Alkalinity, Ammonia, Anion Exchange, Cation Exchange, Cooling Tower, Corrosion, Costs, Efficiencies, Hydraulic Design, Hydrogen Ion Concentration, Iron, Phenols, Pollution Abatement, Polyelectrolytes, Polymers, Scaling, Sedimentation, Separated Sewers, Suspended Solids, Temperature, Water Quality Standards.

*Blow-down, *Corrosive-Scaling Conditions, *Hydraulic Balance, *Stability Index, Blast Furnace, Chemical Stability, Clarifier, Conservative Substances, Cyanide, Dust Collector, Gas Cleaner, Gas Cooler, Gas Scrubber, High-Energy Gas Scrubber, Hydraulic Load, Make-up, Nalco Aquagraph, Non-conservative Substances, Particulate, Ryznar Stability Index, Scale Formation, Secondary Clarifier, Sinter Plant, Spray Tower, Water Separator.

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ABSTRACT

A system was developed and facilities were installed at Interlake, Inc., Chicago Blast Furnace Plant, to treat, clarify, cool, and recirculate the blast furnace and sinter plant wet scrubber effluents in one unified system, in order to effectively re-use these waters and eliminate their discharge into the Calumet River.

Prior to recirculation of scrubber waters, the concentration of contaminants (specifically suspended solids, hexane solubles, ammonia nitrogen, cyanide and iron) in effluent waters consistently exceeded the Illinois code limitations with gross contaminant discharges totaling about 4,100 tons per year. The contaminant intake from the river was about 2,900 tons per year, so the net contaminant discharge to the river was 1,200 tons per year or about 2 pounds per ton of hot metal produced.

After the recycle system was placed in operation, the gross contaminant discharge decreased to 1,900 tons per year, and the net discharge became a negative quantity.

The construction cost of the unified blast-furnace and sinter plant recirculating system was $1,109,400 for this 2-furnace plant producing about 3,200 tons of hot metal and 3,300 tons of sinter per day. Operating costs are about $285,000 per year higher than the costs of operating the old "once-through" water system. Elimination of dredging costs, and increased iron recovery produce savings of about $10,000 per year, so the net increase in plant operating costs is about $275,000 per year. This amounts to about $.0001 per gallon of throughput.

This report was submitted in fulfillment of Program No. 12010 DRE between the Federal Water Pollution Control Administration and Interlake, Inc.

CONTENTS

Section Page

I CONCLUSIONS 1

II RECOMMENDATIONS 9

III PRODUCTION PROCESSES 13

IV PRELIMINARY STUDY OF POLLUTION ABATEMENT MEASURES 31

V DESIGN OF RECIRCULATING SYSTEM 45

VI SYSTEM OPERATION - START-UP AND REFINEMENT 53

1. Hydraulic Balance 55
2. Sludge Concentrator 56
3. Coarse Particulates 58
4. Pump and Valve Maintenance 61
5. Control of Chemical Stability - Blast Furnace System 63
6. Control of Chemical Stability - Sinter Plant System 69

VII ANALYSIS OF PERFORMANCE 73

Control of Cyanides and Suspended Solids 73
Control of System Water Temperatures 80
Cost Analysis 83

VIII ACKNOWLEDGEMENTS 87

IX REFERENCES 89

X PUBLICATIONS 91

XI APPENDICES 93

Appendix A - Processes for Effluent Treatment 93

Appendix B - Cyanide Treatment in a Cooling Tower 97

Appendix C - Scale Formation and Control (Stability Index) 99

Appendix D - Notes on Recycle Objectives and Procedures for a Combined Blast Furnace and Sinter Plant Gas Cleaning System for Interlake Steel Corporation 107

Appendix E - Data Tabulation 115

Appendix F - Modifications of the Recirculation System 149

FIGURES

		Page
1.	Chicago Plant Map	14
2.	Blast Furnace Plant	17
3.	Blast Furnace A & B Working Dimensions	22
4.	Chicago "A" Furnace Material Flow Diagram	24
5.	Chicago "B" Furnace Material Flow Diagram	25
6.	Blast Furnace and Sinter Plant Scrubber Water System - Before Recycle	32
7.	Recirculation Without Cooling Tower, In Winter	37
8.	Recirculation Without Cooling Tower, In Summer	38
9.	Recycle System Flow Schematic, Drawing CA-3253	49
10.	Blast Furnace and Sinter Plant Scrubber Water Recycle Systems - As Initially Installed	50
11.	Blast Furnace and Sinter Plant Scrubber Water Recycle Systems - Modified to Discharge Blow-down into Sanitary Sewer	54
12.	Blast Furnace and Sinter Plant Scrubber Water Recycle Systems - Modified to Permit Make-up and Blow-down Either Before or After Cooling Towers	57
13.	Blast Furnace and Sinter Plant Scrubber Water Recycle Systems - Modified to Reduce Load on Sludge Concentrator	59

14.	Blast Furnace and Sinter Plant Scrubber Water Recycle Systems - Modified to Eliminate Flow to Sludge Concentrator	60
15.	Blast Furnace and Sinter Plant Scrubber Water Recycle Systems - Modified with Stand-by Clarifier	62
16.	Blast Furnace Water System Stability During Initial Operation with 50 Percent Blowdown Rate	64
17.	Effect of Reduction of Blast Furnace Water System Blowdown Rate from 50 Percent to 10 Percent	65
18.	Effects of Periodic Purging on Blast Furnace Water System Stability	66
19.	Blast Furnace Water System Stability Under Scaling Conditions Prior to Acid Addition	67
20.	Effect of Continuous Acid Addition on Blast Furnace Water System Stability	68
21.	Sinter Plant Water System Stability During Initial Operation with 25 Percent Blowdown Rate and Intermittent Acid Additions	69
22.	Effect of Increase of Sinter Plant Water System Blowdown Rate from 25 Percent to 50 Percent	71
23.	Sinter Plant Water System Stability with 50 Percent Blowdown Rate	72
24.	Temperature Effect on Saturation pH (pHs)	101
25.	Use of Nalco Aquagraph	105

TABLES

Page

1. Blast Furnace Scrubber Water Recirculating System - Balanced Condition Parameters 2
2. Sinter Plant Scrubber Water Recirculating System - Balanced Condition Parameters 4
3. Cyanide Concentration - Before and After Recycle System 6
4. Mass Intake and Discharge of Pollutants from Chicago Plant 8
5. Blast Furnace Plant Raw Materials 18
6. Particle Size of Blast Furnace Dust 30
7. Typical Analysis Prior to Recycle 34
8. Material Balance Prior to Recycle 74
9. Recycle System Chemical Balance 76
10. Recycle System Mass Balance 78
11. Water Quality Changes in Blast Furnace Scrubber Water System 79
12. Mass Discharge of Pollutants from Chicago Plant 81
13. Recycle System Water Temperatures 82
14. Cost of Recirculating System 84
15. Operating Cost of Recirculation System 85
16. Analyses of the Waters from the Marley Cooling Towers at the Toledo and Chicago Coke Plants 98

SECTION I

CONCLUSIONS

The operating experience gained during the first 22 months of operation of the Blast Furnace and Sinter Plant recirculation systems lead to the conclusions listed below.

Stability and Blow-Down

1. The Ryznar Stability Index, an indicator which relates calcium ion concentration, total alkalinity, dissolved solids, temperature and ph, is a dependable measure for control of the corrosive-scaling condition of a water system. (Appendix C)

   The Interlake blast-furnace scrubber water system is regulated by monitoring the stability index and attempting to control it to a value between 5 and 6. (Page 68)

2. The Interlake blast-furnace scrubber water system stability index is controlled by acid addition and rate of blow-down. (Page 68) Presently, 200 gallons per day of sulphuric acid are added on a continuous basis, to the cooling tower basin.

   Blow-down from the blast-furnace system to the plant sanitary sewers is maintained at about 10%; it can be extracted from either the hot-well or cold-well pump discharge lines, but is normally extracted from the hot-well pump discharge line.

   Table 1, shows the salient parameters of final, stabilized operation of the blast furnace system.

3. The Interlake sinter-plant scrubber water system stability index is controlled by the rate of blow-down. (Page 70) At the sinter plant, blow-down extracted from either the hot-well or cold-well pump discharge lines, is directed to plant sanitary sewers. When blow-down is maintained at about 50%, the stability index fluctuates in a range generally between a value of 4 and 7. (Page 72) In the early days of system

TABLE 1

BLAST FURNACE SCRUBBER WATER RECIRCULATING SYSTEM

BALANCED CONDITION PARAMETERS

Location	Flow (GPM)	Suspended Solids Lbs./Ton of Iron Produced	Ammonia Nitrogen Lbs./Ton of Iron Produced	Cyanide Lbs./Ton of Iron Produced	Phenol Lbs./Ton of Iron Produced	Iron Lbs./Ton of Iron Produced	pH
Make-up Water	650	.15	.0072	.00003	.00003	.0046	8.1
Clarifier Influent	4,500	17.3	1.06	.125	.0017	7.9	8.2
Clarifier Effluent	4,300	.70	1.02	.074	.0004	.16	8.3
Clarifier Underflow	130	16.6	.031	.051	.0013	7.7	8.5
Blow-Down	450	.07	.106	.0075	.00004	.018	8.3
Evaporation Loss	70						

operation, control of the stability index through manual acid additions in the clarifier overflow basin was attempted, but the extent of swings in index (+9 to -3) and the slow response time (3 to 4 days per cycle) resulted in such unsatisfactory control that this practice was abandoned. (Page 70)

Reliable instrumentation for automatic regulation of the stability index is not presently available, so a manual method which has proved to be effective in inhibiting scaling formation in the piping is presently in use at the sinter plant system. When the sinter plant is operating, no acid additions are made. On the plant shut-down shifts (usually one shift per week), acid is added and the system pH is controlled between 3-5 in order to remove scale and clean out the piping system. This method has been very effective.

Significant flow and chemical parameters of final stabilized operation are shown in Table 2.

There is only a minor interaction between the blast-furnace and sinter-plant systems. The only interconnections which remain are the underflow lines from the blast-furnace clarifier to the sinter-plant clarifier, and this is a relatively minor flow, under 200 gallons per minute. Not only does the underflow serve as a blowdown of the blast furnace system, but the unused underflow line can be used for pumping of blow-down from either system to the other.

Solids Removal

4. When operated on a once-through basis without addition of flocculants, the blast-furnace clarifier was about 95% efficient in removing solid particulates, and the sinter-plant clarifier was about 98% efficient. In the recycle systems, with polyelectrolyte additions to the clarifier feed, about 96% efficiency is being obtained at the blast-furnace clarifier, and 98% efficiency has been retained at the sinter-plant.

TABLE 2

SINTER PLANT SCRUBBER WATER RECIRCULATING SYSTEM

BALANCED CONDITION PARAMETERS

Location	Flow (GPM)	Suspended Solids Lbs./Ton of Iron Produced	Ammonia Nitrogen Lbs./Ton of Iron Produced	Cyanide Lbs./Ton of Iron Produced	Phenol Lbs./Ton of Iron Produced	Iron Lbs./Ton of Iron Produced	pH
Make-up Water	360	.086	.004	.00002	.000018	.0025	8.1
Clarifier Influent	690	38.3	.106	.085	.0027	14.4	10.5
Clarifier Effluent	630	.93	.071	.022	.00005	.084	11.0
Clarifier Underflow	50	37.4	.004	.063	.0026	14.3	11.2
Blow-Down	300	.44	.035	.011	.000022	.04	11.0
Evaporation Loss	10						

At the blast-furnace clarifier we are presently feeding a cationic polymer, Nalco 610, in an amount of .05 parts per million, allowing it to mix, and are then introducing an anionic polyelectrolyte, Nalco 676, in an amount of one part per million.

5. There is no tendency for recirculating solids to cause plugging of sprays or other portions of the piping systems. This is logical in consideration of the fact that the clarifiers are at least as efficient as they were formerly, and the recirculated water is normally lower in coarse solids content than intake water from the river has been in the past.

Cyanide Control

6. Particulate compounds of cyanide can be removed by settling. In both a blast-furnace operation and a sinter-plant operation, a portion of the cyanide bearing components are in settleable forms. (Page 42)

7. Simple cyanides can effectively be oxidized by aeration in a cooling tower. This aeration does not result in the release of hydrogen cyanide gas to the atmosphere. (Page 75) As shown in table 3 below, the concentration of cyanide in the recycle system is higher than in a once-through system. (Page 77)

TABLE 3

CYANIDE CONCENTRATION - BEFORE AND AFTER RECYCLE SYSTEM

	CYANIDE CONCENTRATION (ppm)	
	Once-Through System	Recycle System
Water Intake	.050	.014
Blast Furnace Clarifier Influent	1.7	7.53
Blast Furnace Clarifier Effluent	.26	4.64
Blast Furnace Clarifier Underflow	41.	107.
*Sinter Plant Clarifier Influent	8.0	16.3
Sinter Plant Clarifier Effluent	2.0	9.40
Sinter Plant Clarifier Underflow	170.	340.

* Does not include Underflow from Blast Furnace Clarifier

In neither the once-through systems nor the recycle systems are the effluents suitable for discharge to the river. When an acceptably stable operation is reached in the recirculation systems, the residual amounts of cyanide, averaging about 5 ppm in the blast furnace system and 10 ppm in the sinter-plant system, far exceed the allowable .025 ppm. The cyanide content of the combined blow-downs from the recirculating systems is, however, within the 10 ppm limitation of the sanitary sewer code, and these effluents can be discharged to the sanitary sewer for subsequent treatment. Additional dilution by non-cyanide effluents from other sources within the Chicago Plant reduces the cyanide concentration in the sanitary sewer to 2.68 ppm, about ¼ the allowable concentration.

Construction and Operating Costs

8. The construction cost of the recirculating system was $1,109,400 for the 2-furnace plant producing 3200 tons of hot metal and 3300 tons of sinter per day.

   Operating costs are about $285,000 per year higher than the cost of operating the once-through water system. Economies, which should result from elimination of dredging cost payments to the Corps of Engineers and the reclamation value of salvaged iron units, will total about $10,000 per year. Thus the net cost of operating the system is $275,000 per year.

General

The mass discharge of contaminants from the Interlake recirculation system was substantially reduced from that of the once-through system. Table 4, which is a compilation of the various pollutant discharges under both schemes of operation, indicates the reduction in mass discharge, which is achieved in the recirculating system. A net reduction of 2300 tons per year of contaminants discharged to the Calumet River has been effected, and a reduction of 1900 tons per year of total discharge to the river and to sanitary sewers has been achieved.

It should be noted that the net contaminant discharge to the Calumet River, with the recycle system operating, has now assumed a negative quantity. In other words, the Chicago Plant is discharging a lower tonnage of contaminants than are in the intake waters.

One bad side effect of recirculating the blast furnace scrubbing water is a decrease in the efficiency of blast furnace gas cleaning. With a once-through scrubber water system, gas was cleaned to a dust content of about .02 grains per cubic foot of gas. Since the recycle system has gone into operation, average dust content of the gas has been 1½ to 3 times as high as during once-through operation. Increased dust content of blast furnace gas results in increased residue being deposited in hot-blast stove checkers and in the boiler burners. The cause of decreased gas-cleaning efficiency is still being investigated.

TABLE 4

MASS INTAKE AND DISCHARGE OF POLLUTANTS FROM CHICAGO PLANT

	Suspended Solids (lb./min.)	Hexane Solubles (lb./min.)	Ammonia Nitrogen (lb./min.)	Cyanide (lb./min.)	Phenol (lb./min.)
1. Once-Through System -					
A. Intake from Calumet River	10.5	3.7	1.0	.010	.0018
B. Discharges to Calumet River (CO-1, 2, 3, 4)	15.1	3.42	1.02	.082	.0091
C. Net Discharge to River	4.6	- .28	.02	.072	.0073
2. Recycle System					
A. Intake from Calumet River	11.3	1.4	.52	.002	.0024
B. Discharges to Calumet River	7.0	1.41	.40	.002	.0014
C. Net Discharge to River	- 4.3	.01	- .12	-	- .0010
3. Reduction in Discharge of Contaminants to Calumet River	8.9	- .29	.14	.072	.0087
4. Blowdowns to Sanitary Sewer	1.15	.05	.32	.041	.00015

SECTION II

RECOMMENDATIONS

1. A cooling tower should be provided in any blast furnace gas scrubber water recirculating system in which the volume of blow-down is constrained. Water used for blast-furnace gas scrubbing and cooling should be under 110°F., and the recirculating system cooling tower should be designed to remove from the gas cleaning water about 200,000 BTUs per ton of iron produced at the furnaces. A cooling tower is not required in all sinter plant dust collector water recirculating systems, and thorough testing of the sinter plant scrubber system should be conducted to ascertain the water cooling needs and blow-down limitations prior to the design of the recirculating system. (Page 82)

2. Equipment for acid addition should be provided in any blast furnace or sinter plant recycle system, in order to minimize permanent scale formation. This equipment should include complete monitoring instrumentation and automatic controls which will regulate chemical stability and permit the lowest possible blow-down rate while minimizing scale formation. (Page 64) No such controls are presently available, and it is strongly recommended that efforts be made to develop these controls.

3. A dual polyelectrolyte feed system should be provided in order to obtain the most effective solids removal possible. (Page 75)

4. Horizontal pumps should be used wherever possible. Vertical pumps constitute a potential source of high maintenance costs and undependable operation. (Page 61)

5. Wherever waste is not or may not, in the future, be acceptable for discharge to sanitary sewers, treatment facilities must be designed for the processing of all system blow-down. The recirculating system covered by this report was not limited as far as quality of discharge of effluent to sanitary sewers was concerned, so no design of a treatment plant was contemplated other than in the conceptual stages of system design. (Page 35)

6. Every effort should be made to reduce the hydraulic load on a recirculating system. All non-contact waters should be separated from the system and discharged into other channels. The age of a plant may complicate the separation of waters, due to unavailability of dependable piping drawings and the existence of unknown connections and cross-connections. (Page 55)

7. Although it was not included in the design of the system covered by this report, it might be desirable, in future blast furnace scrubber water systems, to separate gas cooler effluent from gas scrubber effluent. Whereas the gas scrubber effluent has a normal dust loading of about 2,000 ppm, the gas cooler effluent averages only about 300 ppm. Gas cooler discharge water could be recirculated in a separate system with blow-down to the more heavily loaded gas scrubber system. (Page 45)

8. There are, to the extent of our present knowledge, no advantages associated with the combining of a blast furnace gas scrubber water system with a sinter plant dust collecting water system. The initial thinking was that a chemical balance of the systems would be made easier if the systems were combined. Blow-down of one system to the other was considered to be a potential advantage in reducing total blow-down and obtaining hydraulic balance. It was also thought that the blending of blow-down might make the effluent more acceptable to the river or the sanitary sewer. These advantages did not materialize, and combining of the

systems is not recommended, but is certainly acceptable if no substantial extra cost is involved.

SECTION III

PRODUCTION PROCESSES

Interlake's Chicago Plant includes 4 separate parcels of land totaling about 500 acres. Generally, the plant is located on the Calumet River, with iron-making facilities on the east side of the river and coke-making facilities on the west side. A high-level suspension bridge carrying a coke conveyor and gas and steam mains connects the two plant areas. The plant map, Figure 1, shows the facilities and their relative locations.

Coke Plant

The coke plant consists of coal unloading and storage facilities, two batteries of 50 Wilputte underjet ovens each and a by-product plant.

The coal mix for coke making includes 3 main coals normally proportioned as follows:

25% Pocahontas Low-Volatile Coal
60% Illinois Coal
15% Pond Creek Coal

Coal is delivered to the coke plant in unit trains of 100 cars. It is unloaded by car dumper and delivered by conveyors to the storage area. Here the stocking system is served by 3 Euclid Twin-Scraper units which handle coal into or out of stock as received or required. The normal coal storage capacity of 150,000 tons can be readily expanded, if necessary.

Coal going to the ovens is reclaimed from the storage area and conveyor fed to a pulverizer and then the mixer building bins. Next it is blended in the desired proportions and conveyed to the oven storage bins. From these bins it is drawn, as required, into the coke-oven larry car or charging car. The larry car, which is designed to hold the amount of coal needed for charging one oven, runs on

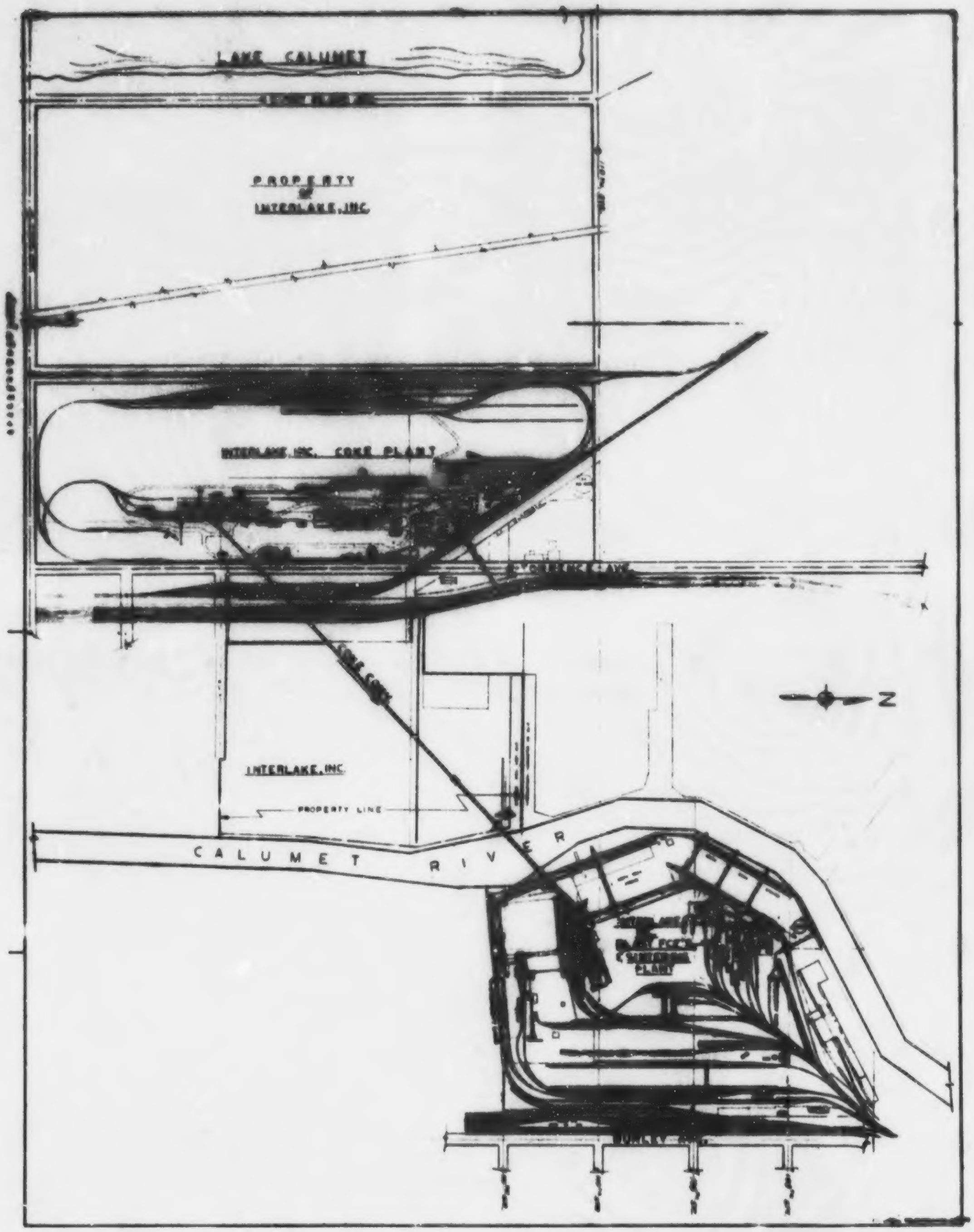
LAKE CALUMET
PROPERTY OF INTERLAKE, INC.
INTERLAKE INC. COKE PLANT
INTERLAKE, INC.
PROPERTY LINE
CALUMET RIVER
PLANT
Z

Fig. 1 Interlake, Inc. - Chicago Plant Map

tracks supported on top of the batteries of ovens. Coal is charged into each oven through three holes, which are immediately sealed when the charging operation is completed. As the coal is heated in the oven, it becomes plastic at 660 to 890°F, forming a fused mass irrespective of its form when charged. Through this range of temperature, volatile matter is given off, rapidly at first, then more slowly up to about 1740°F.

The volatile matters evolved are a combination of gases and vapors. Gases include hydrogen, methane, ethane, carbon monoxide, carbon dioxide and unsaturated hydrocarbons such as ethylene, propylene, butylene and acetylene. Other gaseous compounds present are hydrogen sulphide, ammonia, oxygen and nitrogen. The vaporized liquids in the gases exiting from the ovens include a multitude of hydrocarbons which are generally grouped into three categories, ammonia liquor, tar and light oil.

A good metallurgical coke will retain very little volatile matter -- not over 2 percent -- and will contain 85 to 90 percent fixed carbon. The remainder is ash, sulphur, and phosphorus.

A typical analysis of metallurgical coke would be:

Fixed carbon - 90.0%
Volatile matter - 1.3%
Phosphorus - .005%
Sulphur - .75%
Other ash materials - 7.945%

At the Interlake Coke Plant, the two batteries of ovens, built in 1956 and 1957, are of relatively modern design. They are operating presently on a continuous 16-hour cycle basis. Each oven is designed to receive a charge of 17.4 tons of coal. In 16 hours, 11.6 tons of coke are produced per oven. This results in a yearly coal consumption of 900,000 tons and yearly coke production of 620,000 tons, including 575,000 tons of metallurgical coke suitable for blast furnace use.

Coke discharged from the ovens is quenched at a water spray type quench tower which uses river water as a make-up source, and which recirculates the quenching water. There is no blow-down from this system. Coke is then conveyed over a series of belt conveyors to a screening station at the southwest corner of the blast furnace plant. Chemicals volatilized during the coking process are piped to the by-product plant where ammonium sulphate, tar, pitch, and light oil are removed from the coke-oven gas.

There are no special provisions for sulphur removal in the coke plant gas system; the gas leaving the plant has a sulphur content of from 1 to 2 grains per cubic foot.

Sulphur is in the form of H_2S.

Blast-Furnace Plant

In the ironmaking area, east of the Calumet River, there are two blast furnaces, ore unloading and storage facilities, a coke-screening station, a sinter plant, a boiler-house, two 2-strand pig machines, a pig storage yard, and miscellaneous supporting facilities.

Raw Materials

The map of the Chicago Blast Furnace Plant, Figure 2, shows that raw material unloading, storage, processing, and handling are major considerations in a blast-furnace plant. In 1970, the Chicago Plant consumed the quantities of raw materials shown in Table 5.

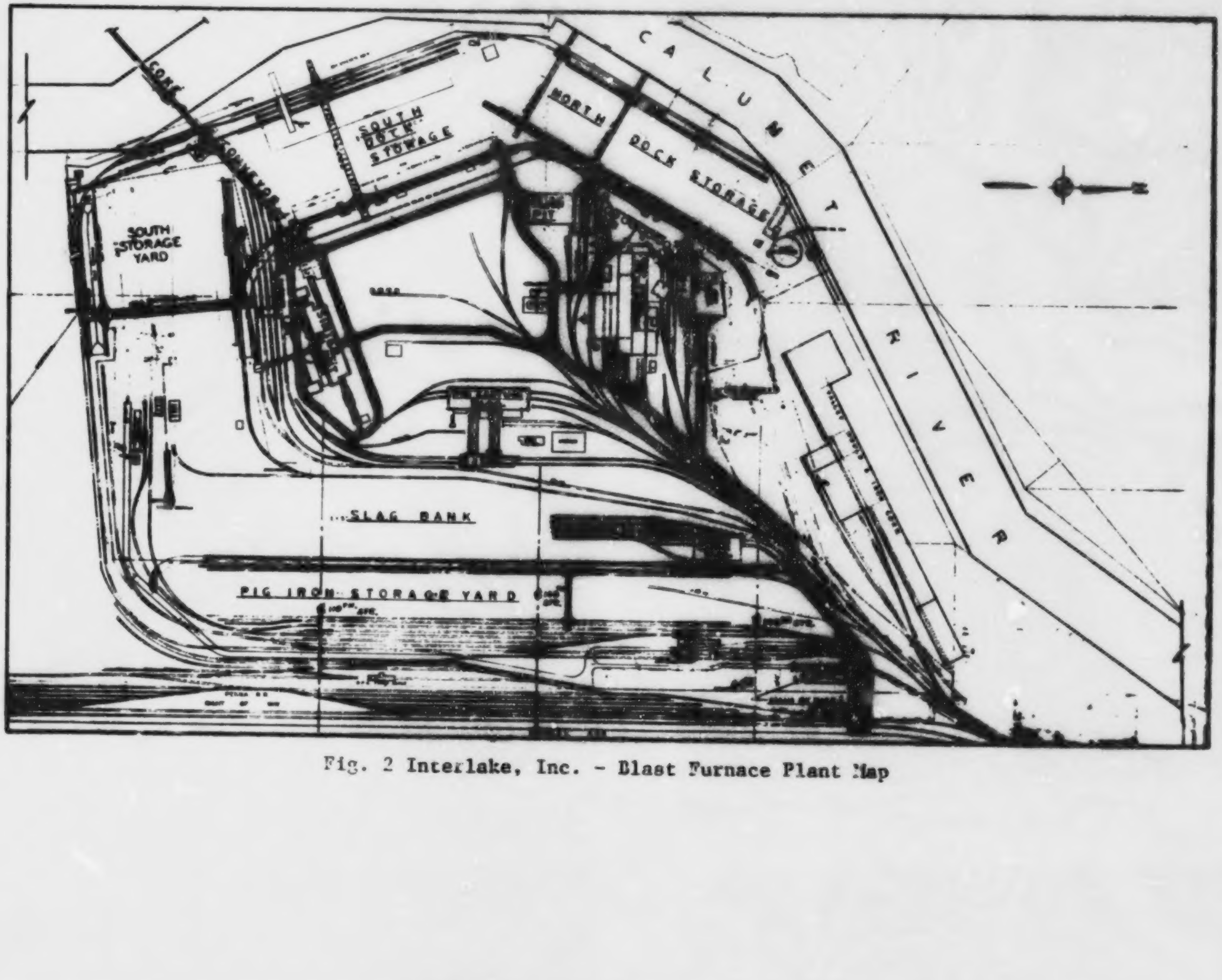
CALUMET RIVER
NORTH DOCK STORAGE
SOUTH DOCK STORAGE
SOUTH STORAGE YARD
COKE CONVEYOR
SLAG BANK
PIG IRON STORAGE YARD
N

Fig. 2 Interlake, Inc. - Blast Furnace Plant Map

Table 5

Blast Furnace Plant Raw Materials

Coke	680,000 tons
Coke Breeze (Fines)	60,000 tons
Limestone (Coarse and Fine)	120,000 tons
Dolomite (Coarse and Fine)	160,000 tons
Iron Ore (55% Fe)	320,000 tons
Pellets (62% Fe)	1,250,000 tons
Sinter (53% Fe)	500,000 tons
Scrap	60,000 tons
Miscellaneous Iron-bearing Materials	250,000 tons

Inasmuch as the quantities of raw materials handled are so large and deliveries to the plant may be seasonal, control of raw material movement is of utmost importance. The raw material storage capacities are limited, and the optimum quantities of some materials are somewhat unpredictable, due to changes in iron analysis and in raw material prices and availability.

Ore, sinter, pellet and flux (limestone and dolomite) storage is provided in 3 storage yards: the north dock storage, 780 feet long by 210 feet wide; the south dock storage, 650 feet long by 350 feet wide; and the south storage yard, 497 feet long by 390 feet wide. The north and south docks will each accommodate a lake carrier of the longest type. Materials are unloaded from carriers by means of an ore unloading tower and unloading bridges with lifting aprons. Two 5-ton bridges serve the north dock, while the south dock is served by one 10-ton bridge and a 20-ton unloading tower. The south storage yard is served by a 20-ton bridge. A conveyor system serving the entire length of the south dock will accept material from either unloader along this dock and deliver it to a trough under the bridge serving the south storage yard.

Two 50-ton transfer cars operate on a continuous highline track which runs the entire length of each storage yard. A second highline track at the blast furnace stockhouses is used in supplying some coke and most miscellaneous materials to the furnace.

Access to the two highline tracks has previously been provided by a highline approach at the north end of the plant. Now, production facility expansion has necessitated the abandonment of this approach, and an approach connecting into the highline opposite the south storage yard has recently been placed in service.

Sinter Plant

The sinter plant produces an excellent iron-bearing raw material using partly waste materials from Interlake's and other area plants, as well as lower-price fine iron ores which would be impractical to use in their natural condition. The charge material produced, sinter, is also more reducible than ore in the blast furnace and is a desirable furnace burden material in producing even gas flow within the furnace stack and a smoother operating furnace. Alkaline additives to the sinter produce a furnace feed material which can be self-fluxing or even higher in basicity than required for the sinter alone.

The Chicago sinter plant, which is of Dravo-Lurgi design, has a production capacity of 3300 tons per day. The plant does not always operate on a 3-shift, 24-hour basis, and some of its production is sold to other steel companies, so the yearly sinter consumption figure can not be correlated with sinter plant capacity. The plant is of modern design although it was first put into operation in 1960.

Fuel for the sintering operation is brought into the plant, in the form of breeze and fines, by conveyor from the adjacent coke screening station or from ground-level track hoppers. If required, it is ground to the required fineness in a rod mill and then conveyed to a large storage bin. Other raw materials, fine iron ores, flue dust, dolomite and limestone, are brought in through a system of track hoppers and conveyors, screened and stored in large bins. These materials are fed, in closely controlled proportions, onto a system of conveyor belts which carry them to the sinter machine. Flue dust from the blast furnaces, varying from 0 to 10% of the feed, is pugged, or moistened, and also introduced into the system. Filter cake from the slurries collected at the sinter plant clarifier is fed directly onto the sinter feed belt.

Fairly recent additions to sinter plant feed materials include pellet fines, roll scale and several other steel plant offal materials. The proportions of various iron-bearing, flux and fuel materials which are fed to the machine vary over a fairly wide range, depending on the cost and availability of materials, basicity of sinter being produced, and other factors.

The mix is placed on the traveling grates of the sinter machine, where it first passes under an ignition furnace which ignites the coke and other combustibles. An induced draft fan of 290,000 cfm capacity, driven by a 2500 horsepower motor, pulls air down through the bed of material as the grates travel the length of the machine. When the bed reaches the end of the machine, it has been sintered, or burned, to a hard, homogeneous clinker. After discharge, from the machine, the sinter passes through a breaker to reduce it to usable sized pieces. At this point, it is hot-screened and the proper sized portion is carried on the sinter cooler to the load-out tower. The sinter is cooled by having air drawn through the bed of material. At the load-out tower, the sinter product is cold-screened, and material of blast furnace size (+ 1/4") is loaded into a transfer car for transportation to the blast furnace bins, or is conveyed to a storage pile. The -3/8" material separated by hot screens after the sinter breaker, and the -1/4" fines separated at the cold screens after the cooler are recirculated and reintroduced into the mix feed system. Some of the intermediate size material (+3/8"-1") separated at the cold screens, is recirculated as a hearth layer on the sinter grates, to reduce the amount of dust passing into the exhaust system.

Dust produced in the sintering process is drawn down through the wind boxes beneath the traveling grates into the gas main, where the larger particles drop out into a series of dust hoppers. Sinter particles are carried on with the gas and are removed in a series of sixteen parallel high-efficiency cyclone collectors before the gas is emitted from the stack. All dust removed to this point, amounting to about 120 tons per day or over 98% of the total gas solids, is collected on a conveyor and reintroduced into the system. This amounts to about 3% of the raw feed to the sinter machine.

There are in the plant a total of 34 belt conveyors handling raw material and finished product. In order to control the dust generated at the various exchange points and other areas, including the sinter machine discharge, two dedusting systems are operated. System "A" collects air at the sinter machine discharge, hot sinter feeder and screens and other points on the hot and cold fines system. System "B" pickup points are in the cold-screening and load-out building. Both systems utilize wet scrubbers, with the resulting slurry being discharged to the sinter plant clarifier. The dedusting systems exhaust to atmosphere. A more detailed description of these systems is given in Section V.

Blast Furnaces

The focal points of the South Chicago Plant are the two blast furnaces. These furnaces produce the molten iron required by the basic oxygen steelmaking shop at the Riverdale Plant and by the Microdot ingot mould facility located adjacent to the Blast Furnace Plant The furnaces also produce some iron which is pigged and sold as merchant grades of pig iron. Total iron production of the two furnaces is 1,100,000 tons per year.

Figure 3 is a diagrammatic cross-section of a typical blast furnace, identifying the principal elements of construction and indicating the flow of gases through the material burden within the furnace. The working dimensions of the Interlake Chicago furnaces are shown on this cross-section.

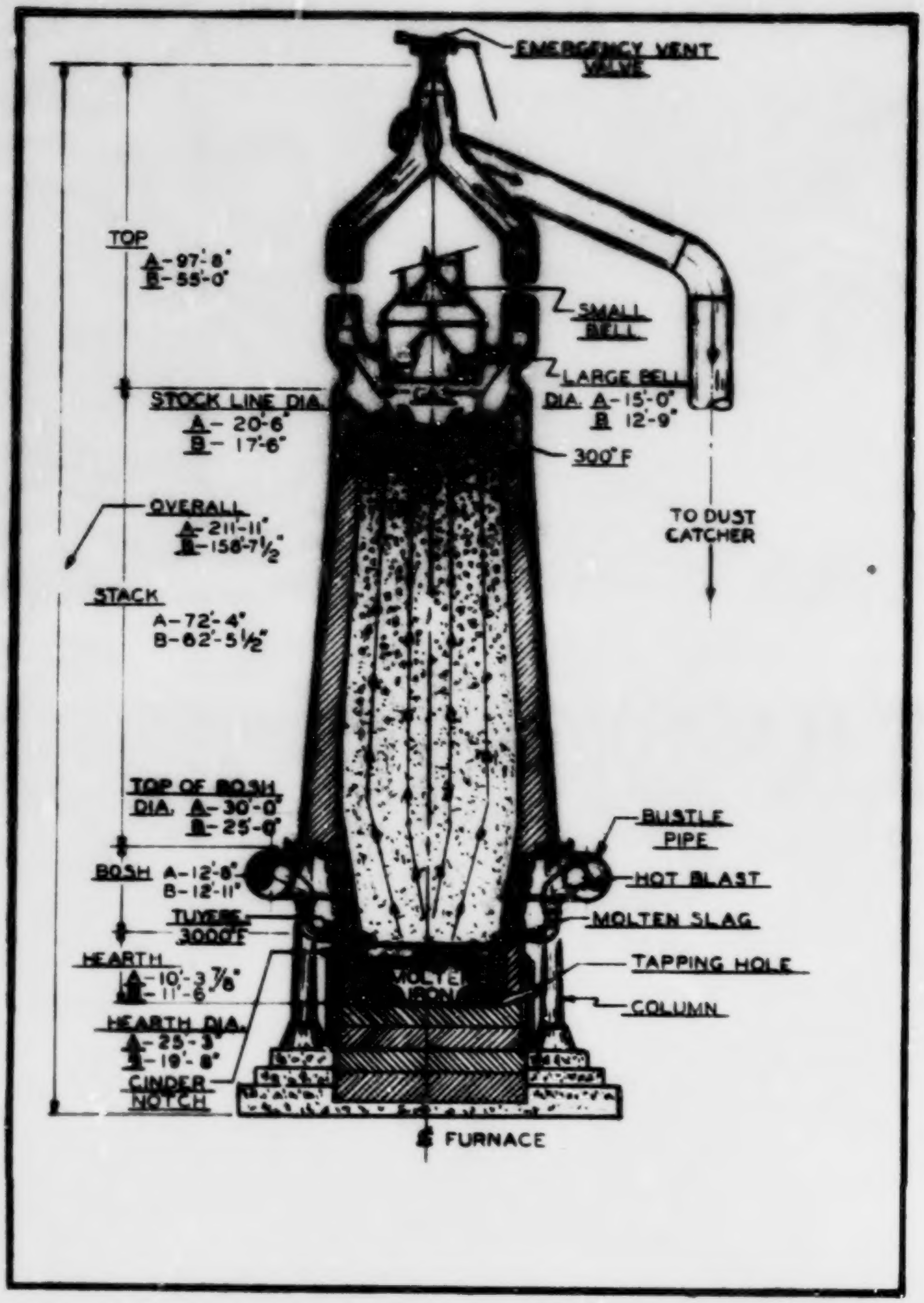
EMERGENCY VENT VALVE
TOP
A-97'-8"
B-55'-0"
SMALL BELL
LARGE BELL
DIA. A-15'-0"
B 12'-9"
STOCK LINE DIA.
A- 20'-6"
B- 17'-6"
GAS
300°F
OVERALL
A-211'-11"
B-158'-7½"
TO DUST CATCHER
STACK
A-72'-4"
B-62'-5½"
TOP OF BOSH
DIA. A-30'-0"
B-25'-0"
BUSTLE PIPE
BOSH A-12'-8"
B-12'-11"
HOT BLAST
TUYERE
3000°F
MOLTEN SLAG
HEARTH
A-10'-3 7/8"
B-11'-6
TAPPING HOLE
MOLTEN IRON
COLUMN
HEARTH DIA.
A-25'-3"
B-19'-8"
CINDER NOTCH
℄ FURNACE

Fig. 3 - Blast Furnaces A & B Working Dimensions

Essentially, the blast furnace process consists of charging iron-bearing materials (ore, sinter, and pellets), fuel (coke) and flux (limestone and dolomite) into the top of the furnace and blowing heated air into the bottom of the furnace. The furnace is a huge steel shell lined with carbon and ceramic refractories. Once started, it runs continuously until all or part of the lining needs renewal, or until demand for the iron drops. Iron-bearing materials, coke and fluxes in alternate layers work their way down from the top, becoming hotter as they sink. In the upper portions of the furnace, reducing gases from the coke and from gaseous or liquid fuels injected with the air blast at the tuyeres react with oxygen released from the heated ore and other iron oxide materials. Midway down the furnace stack, fluxes begin to react with the impurities in the burden to form slag. Next, the iron becomes a porous mass as the burden moves down the stack progressively yielding molten metal which drips down through the burden and collects in the hearth of the furnace. Ash from the coke is absorbed by the slag which drips down to form a pool of molten slag on top of the iron pool. Coke reaches the region of the tuyeres in a white hot condition and reacts vigorously with the oxygen in the hot air blast to produce the heat needed for the blast furnace process, and to form the reducing gases used in the upper portions of the stack.

Periodically (from 5 to 9 times a day) the furnace is tapped, and iron and slag are withdrawn. Iron is conveyed to hot metal cars in which it is transported to the Riverdale BOF shop, the Microdot mould facility or to the pig machine located within the South Chicago Plant.

Figures 4 and 5 are line diagrams of solid material flows at each of Interlake's two Chicago blast furnaces. Material flows shown are based on representative figures for production rates and raw material consumption.

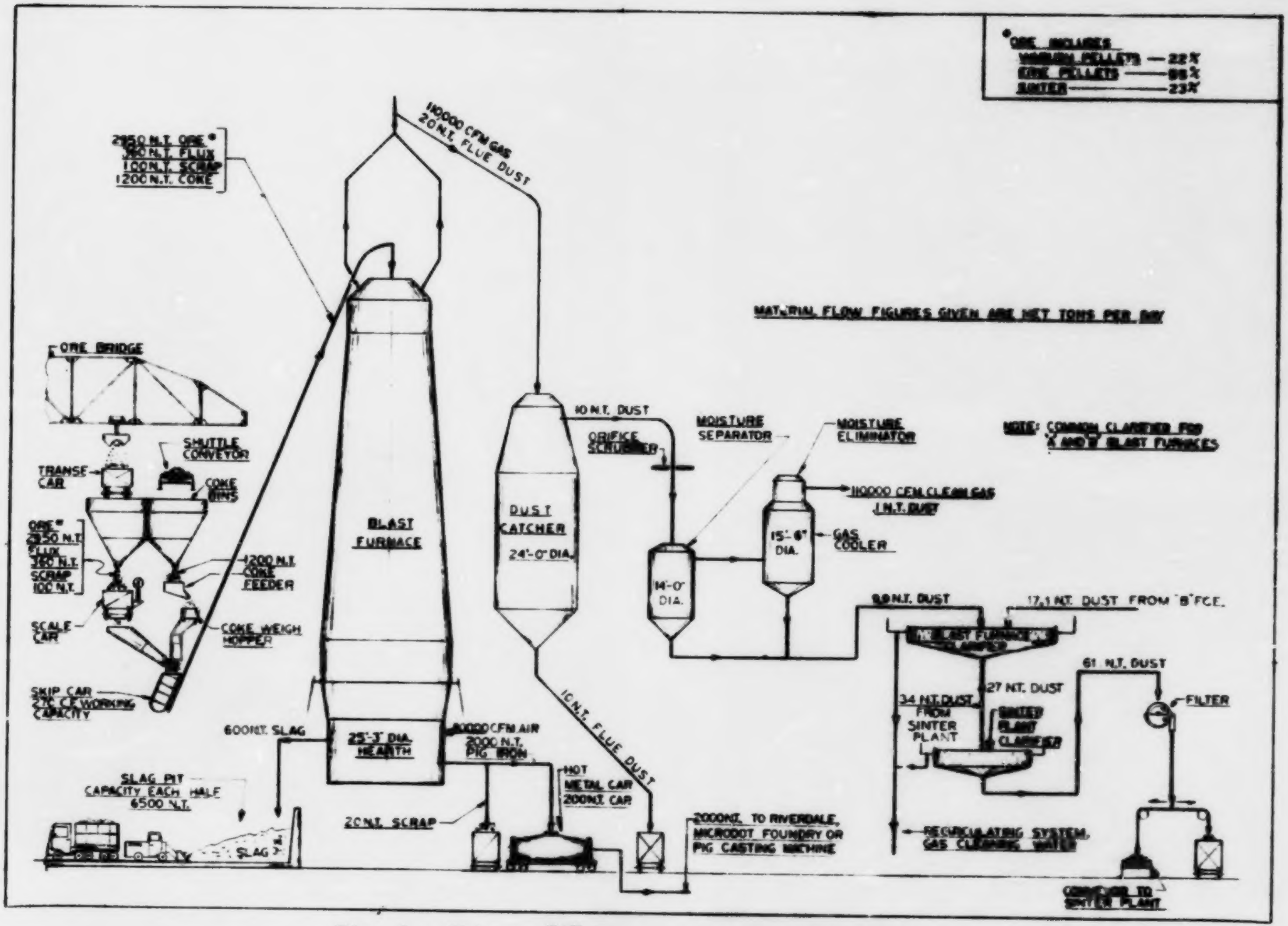
*ORE INCLUDES
WABUSH PELLETS — 22%
ERIE PELLETS — 55%
SINTER — 23%
110000 CFM GAS
20 N.T. FLUE DUST
2950 N.T. ORE*
360 N.T. FLUX
100 N.T. SCRAP
1200 N.T. COKE
MATERIAL FLOW FIGURES GIVEN ARE NET TONS PER DAY
ORE BRIDGE
SHUTTLE CONVEYOR
TRANSE CAR
COKE BINS
ORE* 2950 N.T.
FLUX 360 N.T.
SCRAP 100 N.T.
1200 N.T. COKE FEEDER
SCALE CAR
COKE WEIGH HOPPER
SKIP CAR 270 C.F. WORKING CAPACITY
BLAST FURNACE
25'-3" DIA. HEARTH
600 N.T. SLAG
80000 CFM AIR
2000 N.T. PIG IRON
HOT METAL CAR 200 N.T. CAR
20 N.T. SCRAP
SLAG PIT CAPACITY EACH HALF 6500 N.T.
SLAG
DUST CATCHER 24'-0" DIA.
10 N.T. FLUE DUST
2000 N.T. TO RIVERDALE, MICRODOT FOUNDRY OR PIG CASTING MACHINE
10 N.T. DUST
ORIFICE SCRUBBER
MOISTURE SEPARATOR
14'-0" DIA.
MOISTURE ELIMINATOR
15'-6" DIA.
GAS COOLER
110000 CFM CLEAN GAS
1 N.T. DUST
NOTE: COMMON CLARIFIER FOR 'A' AND 'B' BLAST FURNACES
9.9 N.T. DUST
17.1 N.T. DUST FROM 'B' FCE.
'A' & 'B' BLAST FURNACE CLARIFIER
27 N.T. DUST
34 N.T. DUST FROM SINTER PLANT
SINTER PLANT CLARIFIER
61 N.T. DUST
FILTER
RECIRCULATING SYSTEM, GAS CLEANING WATER
CONVEYOR TO SINTER PLANT

Fig. 4 - Chicago "A" Furnace Material Flow Diagram

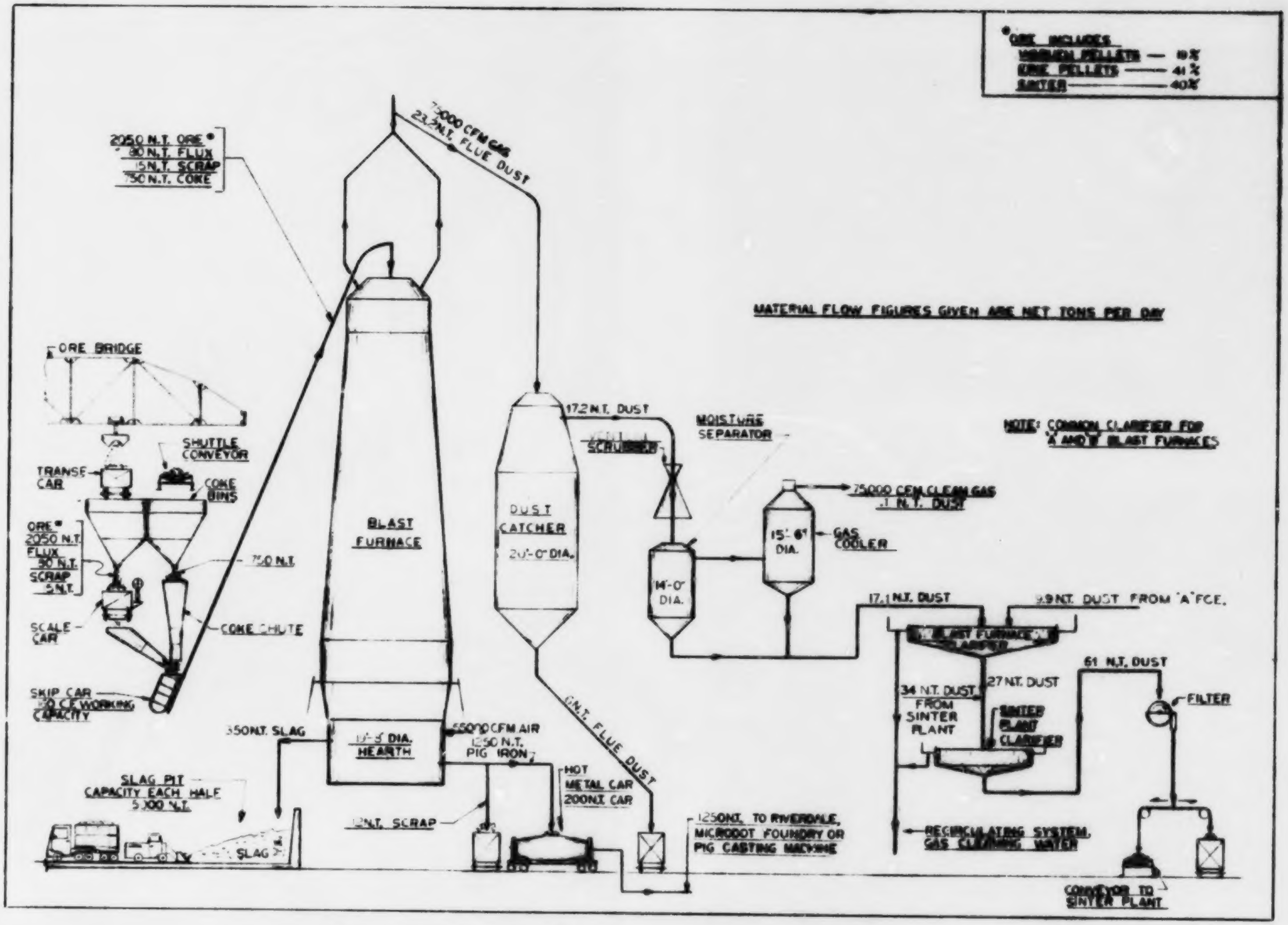
*ORE INCLUDES
PELLETS — 19%
PELLETS — 41%
SINTER — 40%
2050 N.T. ORE*
80 N.T. FLUX
15 N.T. SCRAP
750 N.T. COKE
75000 CFM GAS
23.2 N.T. FLUE DUST
ORE BRIDGE
SHUTTLE CONVEYOR
TRANSF. CAR
COKE BINS
ORE* 2050 N.T.
FLUX 80 N.T.
SCRAP 5 N.T.
750 N.T.
SCALE CAR
COKE CHUTE
SKIP CAR 30 C.F. WORKING CAPACITY
BLAST FURNACE
19'-3" DIA. HEARTH
350 N.T. SLAG
55000 CFM AIR
1250 N.T. PIG IRON
SLAG PIT CAPACITY EACH HALF 5300 N.T.
SLAG
12 N.T. SCRAP
HOT METAL CAR 200 N.T. CAR
DUST CATCHER 20'-0" DIA.
17.2 N.T. DUST
6 N.T. FLUE DUST
SCRUBBER
MOISTURE SEPARATOR
14'-0" DIA.
15'-6" DIA.
GAS COOLER
75000 CFM CLEAN GAS .1 N.T. DUST
1250 N.T. TO RIVERDALE, MICRODOT FOUNDRY OR PIG CASTING MACHINE
MATERIAL FLOW FIGURES GIVEN ARE NET TONS PER DAY
NOTE: COMMON CLARIFIER FOR 'A' AND 'B' BLAST FURNACES
17.1 N.T. DUST
9.9 N.T. DUST FROM 'A' FCE.
BLAST FURNACE CLARIFIER
27 N.T. DUST
34 N.T. DUST FROM SINTER PLANT
SINTER PLANT CLARIFIER
61 N.T. DUST
FILTER
RECIRCULATING SYSTEM, GAS CLEANING WATER
CONVEYOR TO SINTER PLANT

Fig. 5 - Chicago "B" Furnace Material Flow Diagram

The blast furnace plant blowing facilities include 3 turbo-blowers, each rated 70,000 C.F.M. at 25 p.s.i.g. The blowers are equipped with parallel-blowing and split-wind control, so that the combined capacity of either two or three blowers can be split as required between the two furnaces.

It is interesting to note the changes in pollution and pollution control techniques which have occurred within the past 15 years. 15 years ago, over 100 tons of flue dust per day were discharged in the gases passing from the tops of the two blast furnaces. After cleaning of the gas and settling of solids from the wash water, approximately 7,400 tons of solids per year were discharged to the Calumet River. Through design improvements, refinement in operation, and beneficiation of raw materials, it has been possible to reduce the dust rate (pounds of flue dust discharged, per ton of iron produced) from about 150 pounds per ton to the present 25 pounds per ton. The recirculating water systems have been effective in not only eliminating the solids discharged to the river from the gas cleaning systems, but actually brought about, in 1970, a negative net solids discharge. That is, the water returned to the river was, on the average, cleaner than that taken in and used by the plant. This was accomplished at production rates almost exactly twice as high as those existing 15 years ago.

A high percentage (actually about 99 percent) of the solid materials escaping from the blast furnace in its exhaust gases is captured by the gas cleaning system and reclaimed for use as charge material. This is accomplished by a 3-stage cleaning system including a conventional dry dust-catcher, a high-energy wet scrubber and a counter-current spray tower which acts as a combination gas cooler-moisture eliminator.

The dry dustcatcher dust is taken by railroad car to the sinter plant, where it is conveyed to feed bins and eventually fed into the sinter machine mix. Wetted dust from the high-energy scrubber and gas cooler is pumped, with the discharge water, to a water treatment system. The dust in the form of a thickened slurry is then pumped to two disc-type sludge filters located at the sinter plant. The filter cake feeds directly to the sinter machine feed conveyor.

Blast furnace gas is used as a fuel in the blast furnace stoves and the boilers. The more critical requirements for clean and dry gas exist at the stoves, where maintenance of checkerwork cleanliness is an important factor. Gas which contains more than .01 grain of dust per cubic foot is not desirable for use in the small-hole (2-inch square or smaller) checker tile of a modern stove. Excessive moisture in the gas not only depresses the thermal value of the gas but produces a sloppy condition at the stove burners.

Iron Production Wastes

Based on the variety of constituents in iron ores, fuels and fluxes, and on the temperatures and pressures which exist in an operating furnace, the chemical reactions which are carried out in a blast furnace are multitudinous and to some degree indeterminate.

The reduction of iron oxides to metallic iron proceeds in accordance with a dozen or more reactions involving C, CO, CO_2, Fe_2O_3, Fe_3O_4, FeO and Fe. These reactions have been the subject of many comprehensive studies, but they are not germane to the subject of formation of contaminants in the blast furnace gas.

The significant pollutants in blast furnace gas scrubber water are cyanide, phenols, ammonia, suspended solids, temperature and pH. The source of these pollutants is as follows:

Cyanide

The hot blast of air blown into the furnace at the tuyeres has the usual proportions of O_2 and N_2. The action of the nitrogen of the blast upon the hot carbon in the hearth results in the formation of small quantities of cyanide. Cyanide has a strong affinity for the sodium and potassium present in the fuel ash, and as a result, cyanides of the alkali metals are present in the gases leaving the hearth zone. Typically, this reaction proceeds as shown. (4).

$$K_2 CO_3 + 4C + N_2 = 2KCN + 3CO$$

The cyanide, which is a powerful reducing agent reacts:

$$KCN + FeO = Fe + KCNO$$

The resulting potassium cyanate passes upward in the gases and is decomposed by CO_2 into carbonates with the liberation of nitrogen, thus:

$$2KCNO + CO_2 = K_2 CO_3 + CO + N_2, \text{ or}$$

$$KCN + KCNO + CO_2 = K_2 CO_3 + 2CN$$

The potassium carbonate is largely deposited in the cooler parts of the furnace and carried downward by the descending materials to the hearth, where it can again act as a base for cyanide formation.

The precise mechanism of formation and circulation of cyanides within the furnace is open to speculation, however, it is a fact that a quantity of cyanides escapes from the furnace in the outlet gas and in the flue dust. This is the quantity which pollutes the gas scrubber water.

The discharge of cyanide from a blast furnace occurs in an irregular pattern of flow, and a chemical treatment of the gas is therefore rendered more difficult. It is possible that these variations in cyanide evolution may be a result of channeling of gases through the burden in the furnace stack. This is a factor which cannot be effectively controlled in present-day normal blast furnace practice.

Phenol

The entire list of sources of phenols is not pinpointed but it is apparent that much of these originate in the volatile residue in the coke, or possibly in other organic gangue constituents of the furnace raw materials.

At some coke plants, a potential source of phenol is introduced by the technique of quenching coke with waters which contain phenolic wastes from coke gas by-product plant operations. Interlake does not use such waters for quenching, but employs a separate recirculating quench water system with river water provided as make-up. Whatever the exact source, some phenols are picked up in the gas scrubber water and carried into the blast furnace recycle system.

Suspended Solids

Fine particles which enter or are formed in the top of the furnace are picked up by the high gas velocities existing in the furnace stack and are conveyed through the raw gas system.

The nature of particulate matter escaping from the stack will vary from furnace to furnace, depending on the composition of the raw materials, furnace operating techniques and other variables. Some of the constituents which are carried over with the gas are Fe_xO_y, $CaCO_3$, CaS, $MgCO_3$, SiO_2, CaO, MgO, KCN, and Carbon. In regard to particle size, one sample of particulate matter analyzed as shown in Table 6.

Table 6

Particle Size of Blast Furnace Dust

Particle size	+ 635 microns	11%
	635 - 423 microns	13
	423 - 317 microns	8
	317 - 254 microns	7
	254 - 169 microns	7
	169 - 127 microns	6
	127 - 102 microns	3
	102 - 94 microns	5
	94 - 78 microns	2
	smaller than 78 microns	38
		100%

In the Interlake gas systems, as in most blast furnace gas systems, the dustcatchers collect from 25% to 75% of the particulate matter. About 99% of the particulates which are not captured in the dustcatchers are collected in the gas scrubbing water and processed in the recycle system.

Temperature

As is the case with many blast furnace operating conditions, the top temperature is a function of many factors, and may vary from over 1000° F. (with abnormal furnace filling) to under 212° F. A more normal range for top temperature is between 250 and 400° F. As discussed in more detail in Section IV, it is desirable, in the gas cleaning system, to cool the gas to a temperature which inhibits the vapor content of the gas. Most of the thermal energy removed from the gas is transferred to the scrubbing water, with the resultant thermal pollution of this water.

pH

The alkaline condition of the gas cleaning water is a result of a predominance of alkaline minerals and chemicals in the fumes and dust emitted in the furnace top gases. The turbulent contact between gases and waters in the scrubbing and cooling units promotes an effective absorption and pick-up, by the water, of these alkaline constituents.

SECTION IV

PRELIMINARY STUDY OF POLLUTION ABATEMENT MEASURES

History

Historically the cleaning of blast-furnace gas was originally undertaken, not on a pollution abatement basis, but rather as a requirement to prepare the gas for combustion in various auxiliaries of the furnace. Blast-furnace gas-fired boilers became more sophisticated; hot-blast stoves were designed with smaller checker openings in order to acquire more heating surface; cleanliness requirements for coke-oven underfiring became more stringent; in short, the fine cleaning of gas became a necessity. This cleaning was accomplished in wet scrubbers and wet electrostatic precipitators, with the effluent slurries being treated in a clarifier or settling basin before discharge to the waterways.

Original Water System Design

The gas-cleaning water system at Interlake's Chicago plant was somewhat unusual, in that the slurry underflow from a primary clarifier at the blast furnaces was pumped to a secondary clarifier located adjacent to the sinter plant.

The secondary unit clarified the effluent water from two sintering plant environmental control systems, as well as the blast furnace clarifier underflow.

A diagram of this system is shown in Figure 6. The system had the advantage of consolidating all solids-containing wastes at one location, where the solids could be recovered and fed directly to the sinter plant raw material feed conveyor.

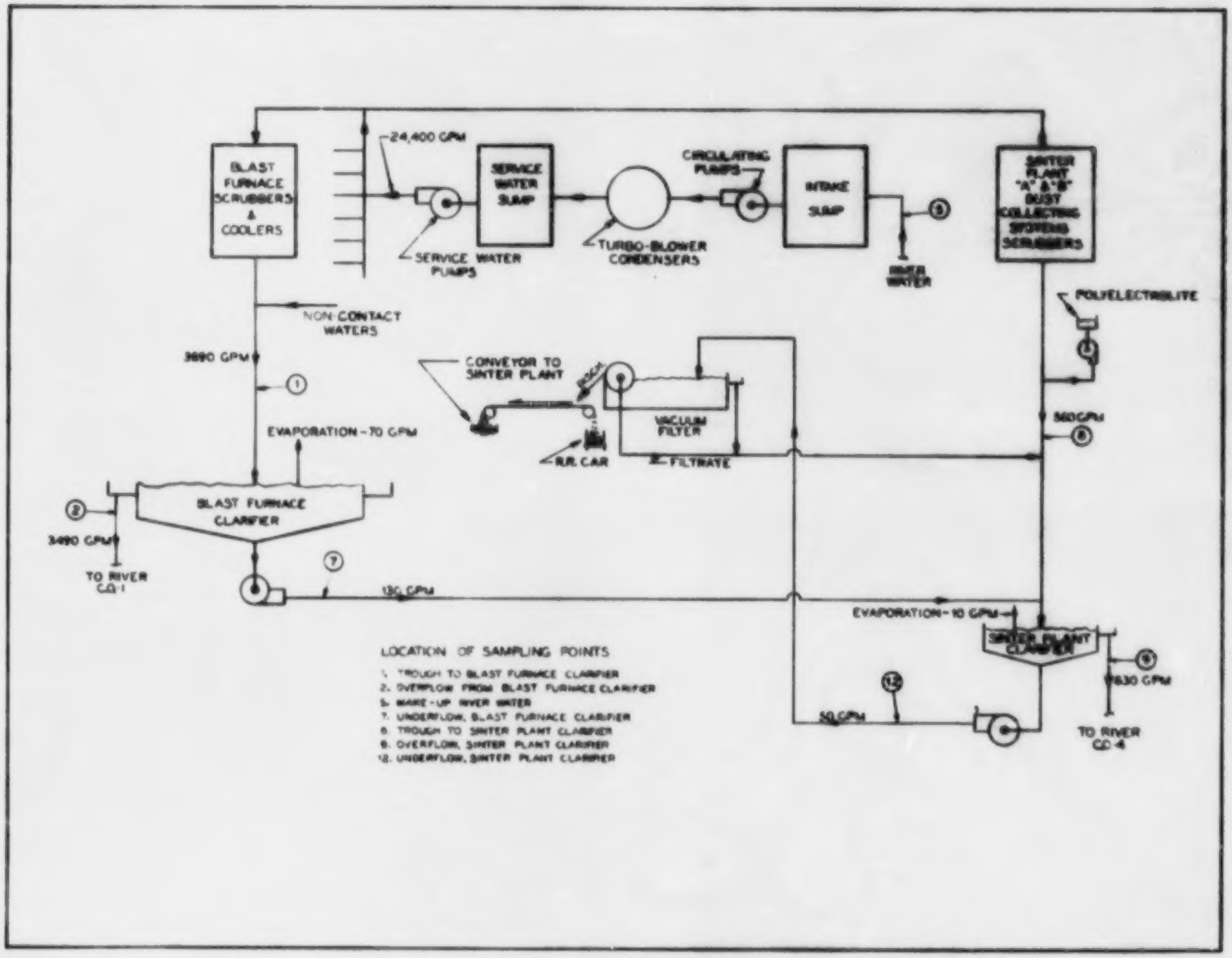
BLAST FURNACE SCRUBBERS & COOLERS
24,400 GPM
SERVICE WATER PUMPS
SERVICE WATER SUMP
TURBO-BLOWER CONDENSERS
CIRCULATING PUMPS
INTAKE SUMP
5
RIVER WATER
SINTER PLANT "A" & "B" DUST COLLECTING SYSTEMS SCRUBBERS
POLYELECTROLITE
560 GPM
8
NON-CONTACT WATERS
3690 GPM
1
EVAPORATION - 70 GPM
CONVEYOR TO SINTER PLANT
CAKE
R.R. CAR
VACUUM FILTER
FILTRATE
2
3490 GPM
TO RIVER CO-1
BLAST FURNACE CLARIFIER
7
130 GPM
EVAPORATION - 10 GPM
SINTER PLANT CLARIFIER
9
630 GPM
TO RIVER CO-4
12
50 GPM
LOCATION OF SAMPLING POINTS
1. TROUGH TO BLAST FURNACE CLARIFIER
2. OVERFLOW FROM BLAST FURNACE CLARIFIER
5. MAKE-UP RIVER WATER
7. UNDERFLOW, BLAST FURNACE CLARIFIER
8. TROUGH TO SINTER PLANT CLARIFIER
9. OVERFLOW, SINTER PLANT CLARIFIER
12. UNDERFLOW, SINTER PLANT CLARIFIER

Fig. 6 - Blast Furnace & Sinter Plant Scrubber Water System Before Recycle

The first effluent clarity controls imposed on Interlake were a result of agreements with the U. S. Corps of Engineers. Starting in the year 1954, Interlake commenced continuous sampling of all effluents from the Chicago Blast Furnace and Coke plants. Agreements were reached, in accordance with which Interlake paid the Corps of Engineers for dredging of the Calumet River on a basis commensurate with the measured discharge of solids from the plants. However, it became obvious, even prior to Federal, State, and Metropolitan Sanitary District moves into environmental control, that limitations on discharges into waterways were imminent, and efforts towards better clarification of the effluents were instituted by Interlake. These efforts took the form of increased usage of the blast furnace clarifier, and measured additions of flocculents to improve the efficiency of the sinter plant clarifier.

Interlake's responsible and successful efforts to satisfy the Corps of Engineers, resulted in an early appreciation of the need for water pollution abatement. The problems related to water supply, treatment, distribution, and pollution control became apparent. In 1963 the firm of Stanley Consultants was retained to perform a complete water inventory of the Chicago Plant. This survey served as a basis for efforts to improve water distribution and pollution control.

During the period prior to 1967, a state of limbo existed in the field of pollution abatement, because of the lack of any definite direction by the various governing agencies. A need existed for viable criteria on which design of abatement systems could be based. This void was filled by SWB-15, a law adopted June 28, 1967, by the Illinois State Water Board, which established standards for the constituents and properties of all effluents. Based on these standards, Interlake instituted a study of the Chicago Plant effluents and the need for treatment of these effluents. Table 7 records the pertinent criteria set in SWB-15 and typical analyses of Chicago Blast Furnace Plant intake and outfalls, prior to the installation of the recirculating systems (Flow as diagrammed in Figure 6). The data in Table 7 generally represent the average values of a number of grab sample analyses. Not all analyses were performed on each

TABLE 7

TYPICAL ANALYSIS PRIOR TO RECYCLE

Location	Flow (GPM)	Suspended Solids (ppm)	Hexane Solubles (ppm)	Ammonia Nitrogen (ppm)	Cyanide (ppm)	Phenol (ppb)	Iron (ppm)	pH
Intake	24,400	51.5	18.	5.0	0.050	9.0	3.3	7.7
North Sewer (CO-2)	11,300	80.6	18.	5.3	0.40	47.0	5.9	8.3
South Sewer (CO-3)	7,220	77.2	25.	1.4	0.41	13.0	2.5	8.1
Blast Furnace Clarifier Influent	3,690	928.	8.0	16.	1.7	171.	371.	8.4
Blast Furnace Clarifier Effluent (CO-1)	3,490	44.6	6.0	10.	.26	80.0	11.5	8.4
Blast Furnace Clarifier Underflow	130	25,200	74.	10.	41.	2760.	10,200	8.6
*Sinter Plant Clarifier Influent	560	9,240	12.	35.	8.0	400.	2,770	10.3
Sinter Plant Clarifier) Effluent) Sinter Plant Outfall) (CO-4))	630	305	10.	27.	2.0	298.	35.1	10.3
Sinter Plant Clarifier Underflow	50	165,000	210.	27.	170	7900.	57,100	10.3
Steam & Evaporation Loss	1,760	-	-	-	-	-	-	-
Code, SWB-15	-	25	15.	2.5	.030	200.	10.0	6-10

*Does not include Underflow from Blast Furnace Clarifier sample, but it is believed that the tabulated figures are representative of the system water quality and quantity. With the exception of tests for iron, analytical procedures used to determine concentrations as shown on Table 7 were performed in accordance with "Standard Methods for the Examination of Water and Waste Water", 12th Edition, 1965. Iron analyses were performed by atomic absorption spectrophotometry.

Table 7 indicates that the effluents were not in compliance relative to allowable discharge of suspended solids, ammonia, cyanide, phenols, iron, and pH.

Studies were promptly instituted to investigate the most practical method for control of the polluting constituents. First efforts were directed towards treatment of the effluents to allow continued discharge to the Calumet River. Numerous treatment processes were considered and evaluated in this study. See appendix A for details of some processes which were evaluated. It was eventually decided that the volume of water requiring treatment, the state of development of the systems, the possibility of changing standards for pollution abatement and the limited area for facilities were going to result in a capital expenditure of prohibitive proportions and a system of questionable effectiveness.

It appeared, therefore, that the logical approach to Interlake's problem was a recirculating system, in which the effluent from the two clarifiers would be recycled for use in the various gas scrubbing units. Some blast furnace plants had used, and still use, such a system, but none had incorporated sinter plant wet scrubbers into an integral recycling system with blast furnace gas-cleaning units. In considering the feasibility of a recirculating system, several important questions had to be answered and determinations made. These were:

1. Are cooling towers required?

2. What water stability problems would be encountered, and how could these be solved?

3. At what level of concentration would the various contaminating constituents stabilize?

4. What effects would flocculents have in the system?

The study of these questions proceeded with the following considerations and decisions.

1. Are cooling towers required? Blast furnace gas leaving a wet scrubber will be saturated with moisture. The temperature of the gas at this point, therefore, determines the amount of moisture (in vapor form) that will be contained in the gas. This amount varies drastically with relatively small differences in temperature. For example, gas at 100°F. will carry 20 grains per cubic foot, while gas at 120°F. will carry over 34 grains per cubic foot, a 72% increase.

   Excessive moisture in the gas not only decreases the effective calorific value, but it results in heavy condensation in gas mains, burners, etc. It is, therefore, desirable to cool the gas to a fairly low temperature in the wet scrubbers or gas coolers following these scrubbers, and this is accomplished by maintaining a low temperature in the water going to scrubbers and gas coolers. Water temperature is also one of the variables which effects chemical stability, so it is an important factor in scale deposition. At the Chicago Plant, a water temperature of under 110°F. is believed to be desirable.

   Thermal balances were prepared in an investigation of the amount of blow-down required to maintain the desired operating temperatures, when using the clarifier as the only means of heat transfer. From the thermal balances, a family of curves, shown in Figures 7 and 8, were developed. These curves indicate that a blow-down rate of 25-40% during the summer months, would have to be maintained in order to reduce the water temperature as required. Because of the limitations in allowable quality of flow of effluent to the river and the limited hydraulic capacity of sanitary sewers,

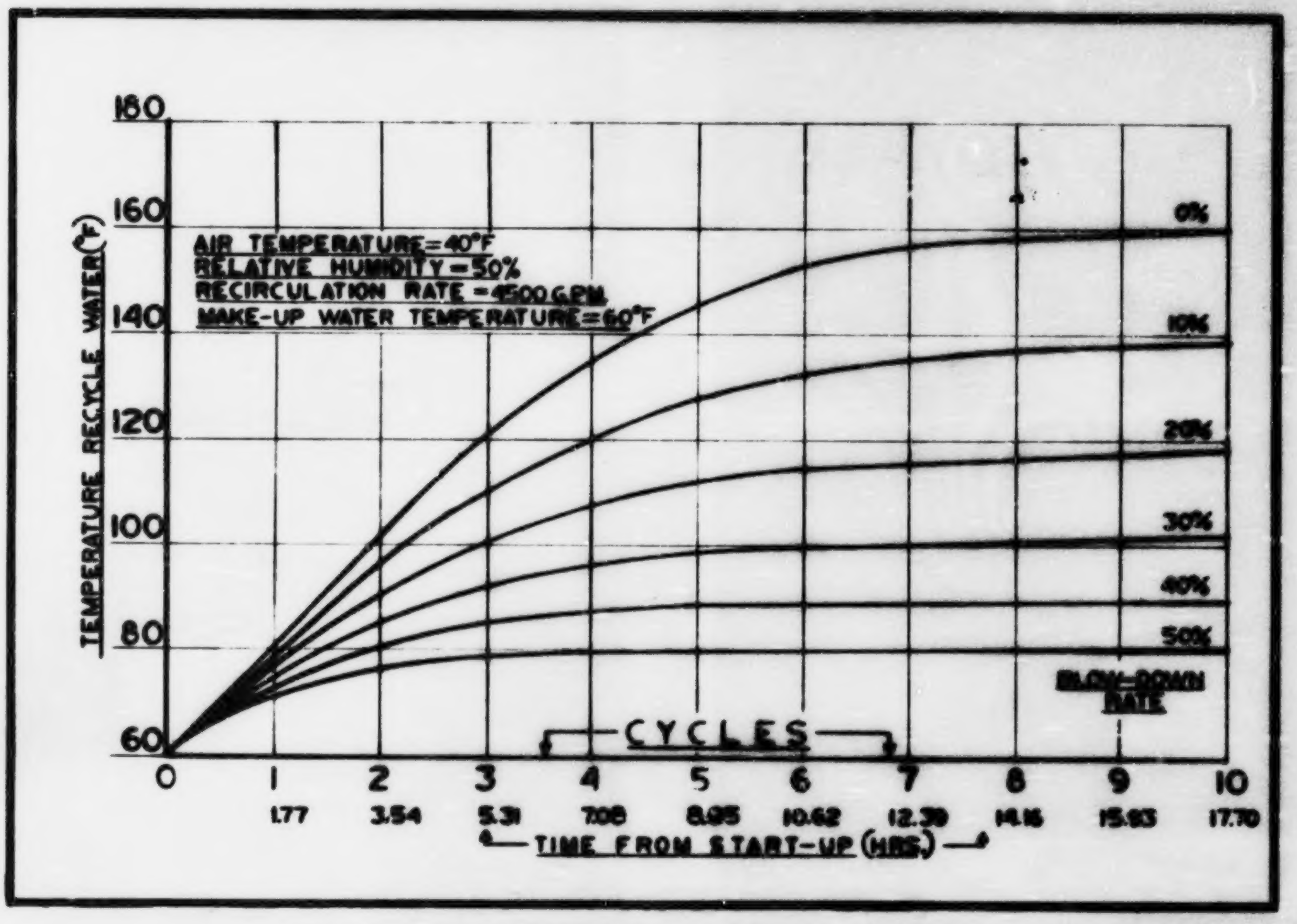

Fig. 7 - Recirculation Without Cooling Tower in Winter

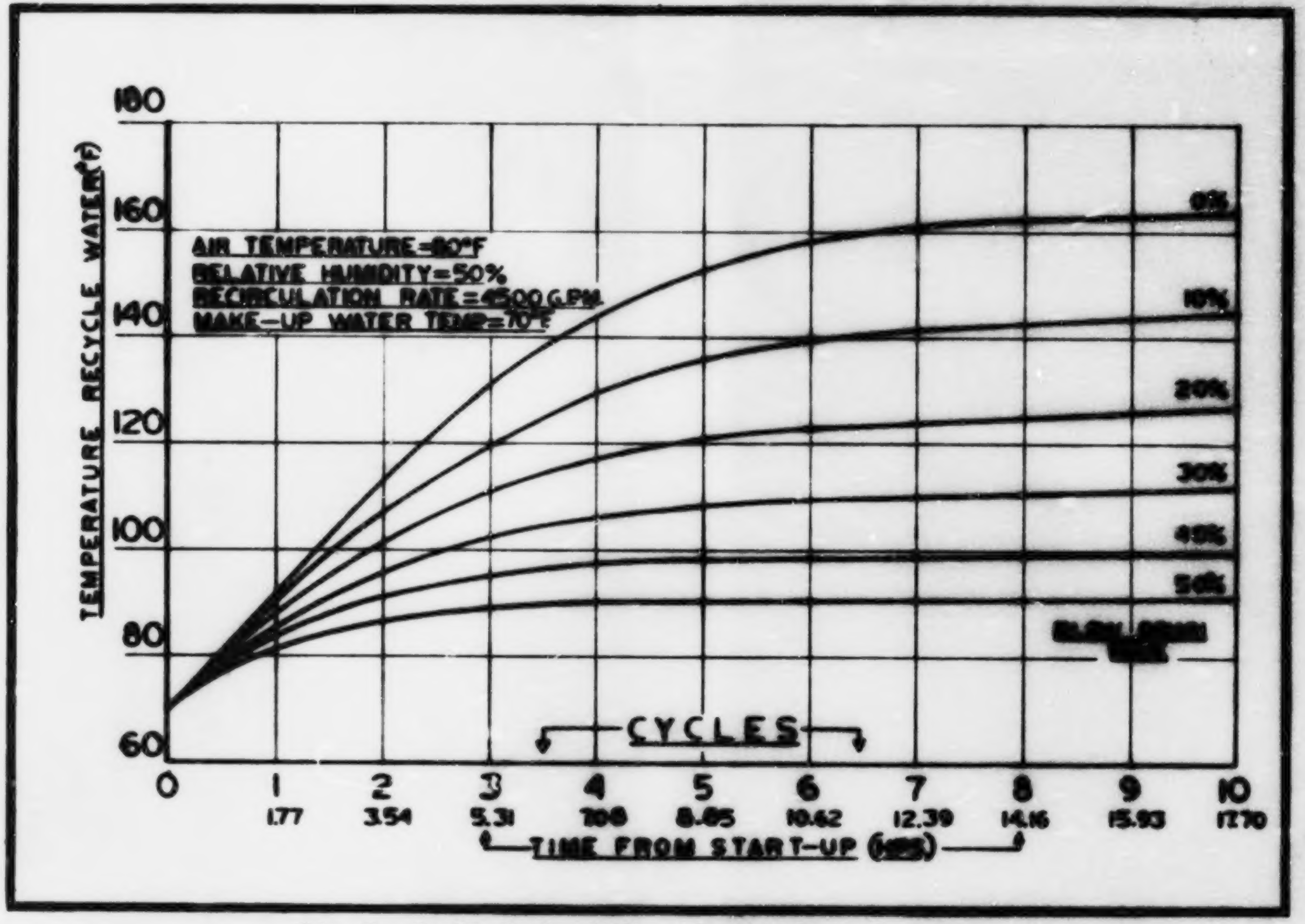

Fig. 8 - Recirculation Without Cooling Tower in Summer

we could not tolerate a blow-down of this magnitude, so a cooling tower was included in the blast furnace recycle system.

The sinter plant dust collector water temperature can vary over a fairly wide range, as the conditions at collection points change or the distribution of collected air is changed.

A need for low water temperature at the dust collectors, in order to reduce the air temperature leaving the collectors, does not exist, as this air is merely exhausted to atmosphere through a fan. There is, however, another reason for maintaining a low water temperature, the desirability of minimizing the build-up of alkali deposits within the recycle system. The water temperature is inter-related with water stability.

Based on a combination of measured and assumed operating information, it was concluded that the sinter plant scrubber water system also required a cooling tower to maintain desirable temperatures in the system.

2. What water stability problems would be encountered and how could these be solved? As stated earlier, the purpose of the gas scrubbers and counter-current spray towers is to cool the gas and to remove suspended particulate matter so that the blast furnace gas is a suitable fuel for blast furnace stoves, boilers, and other auxiliaries. In achieving these results gas cleaning water also picks up dissolved inorganic and organic materials.

   Many of these materials are considered pollutants to receiving waters. To reduce the level of pollutant discharges in the clarifier overflow, a scheme of operation in which a large proportion of the overflow is fed back to gas cleaning units is employed. The principal questions to be discussed pertain to materials, picked up by the washer water, that limit the level of reuse or recycle of the water. No gas cleaning system can operate on complete recycle;

material balances must be satisfied. The water has a finite transport capacity for suspended and dissolved material and for heat. In order to maintain its ability to clean the gas, the gas cleaning water must be processed in such a way that incremental amounts of suspended and dissolved materials and heat are removed from the water. If the transport capacity of the water is exceeded, the gas cleaning operation will fail. It was an objective of preliminary studies to point out the limiting factors that control the gas cleaning operation and to achieve operating conditions in which materials in excess of those which can be carried by the washer water are removed in the treatment device and not at indeterminate points in the system. Two contrasting waste treatment problems exist. In the once-through operation, a high-volume-low concentration stream must be treated. A recycle operation will need some type of treatment for the main water stream but, in addition, will have a blowdown stream which is a low volume-high concentration stream. The character of this blow-down stream is influenced by two not necessarily compatible factors, namely, the concentration and treatability of the pollutants in the stream and the concentration and transport limiting characteristics of control materials in the main gas cleaning water. In the Interlake recirculating system, the latter was the governing factor.

The chemical and physical contaminant parameters of the water system can be classified as conservative and non-conservative. Conservative substances, such as sodium and chloride, are added to the water by the gas cleaning process and generally tend to build up in concentration with time. By the means of blowing down, or discharging from the system a portion of the gas cleaning water, the concentration of the conservative substances can be held nearly constant. Theoretical analysis of conservative substance control is detailed by McMichael, et al (1). Non-conservative substances are also added to the water by the gas cleaning process.

These substances may undergo chemical reaction and be precipitated, volatilized, or otherwise lost from the system, Their behavior is not readily predictable. Included in the non-conservative or interacting parameters are calcium, alkalinity, pH, ionic strength, ammonia, phenol, cyanide, and temperature. These non-conservative materials are also effected by, and can be partially controlled by, blow-down. It is necessary, for operational control, to determine the response of the water recycle system with regard to the non-conservative substances. Broadly, some non-conservative substances may change concentration by large amounts, reach saturation levels, precipitate, and entirely change the chemical composition of the recycle water stream. The prediction and control of this chemical system is the principal problem of the recycle operation. Ideally, this system should be controlled with a minimum of outside activity.

It was hoped that control of the non-conservative substances could be managed by the same technique as used for control of conservative substances, that is, blow-down from the system.

Observations of blast furnace gas cleaning systems on recycle show that the principal failures are due to the plugging of spray nozzles, deposits in venturi or orifice throats, and the closing of transport pipes by precipitated materials (1). Chemical analyses of such materials show they are mainly calcium carbonate. Suspended material does not seem to be a controlling factor. Carbon dioxide and calcium oxide in the gas react with the wash water to change the calcium carbonate equilibrium. Other materials in the gas add incrementally to the total dissolved solids.

Measurable amounts of iron, sodium, potassium, magnesium, chloride, sulfate, and ammonia are found in addition to other constituents previously mentioned. The different levels of these materials depend on the furnace burden and method of operation.

Many arbitrary rules of operation exist within the steel industry regarding recycle operation (1). Some general statements indicate that systems on 80 percent recycle (or 20 percent blow-down) generally perform like once-through operations. Tighter systems require more care than once-through operations. Some companies control their recycle system through blow-down and make-up water, keeping the total dissolved solids (or electrical conductivity) below an empirically determined value. Other companies operate similarly but monitor total alkalinity. One successful recycle operation controls its system by acid addition to keep the pH below an empirically determined level. Each of these systems has had its failures, and by one mechanism or another has wandered to an apparently satisfactory working level.

3. At what level of concentration would the various contaminating constituents stabilize in the blast furnace recycle system? Our primary concern, at the outset of our studies of a recycle system was the build-up of cyanide.

Cyanide in blast furnace waters exists in three complex forms: (1) as an organic amino compound, (2) a non-metallic salt, and (3) a metallic salt. It was believed that a reduction in cyanide content would be accomplished by the treatment of the scrubber water with polyelectrolytes and subsequent settling of the metallic and non-metallic cyanide salts in the clarifier. Originally it was intended that an anionic polyelectrolyte be added ahead of the clarifier; cationic particles such as iron would be agglomerated, thereby improving the collection efficiency by 60-70%. A product made by Nalco Chemical Company, Nalco #673 was selected for this service and bench tests were conducted to determine the effectiveness of the proposed additions. This product, by itself, improved the suspended solids removal as anticipated, but the tests showed that further improvement was needed in order to bring the cyanide and suspended solids levels down even further.

Experimentation showed that we could improve the efficiency of the suspended solids removal, and hence the removal of the cyanide, by first introducing a cationic, low molecular weight polymer, Nalco 610, and following with an anionic polyelectrolyte, Nalco 676. An improved efficiency of solids removal of over 95% was believed to be possible, and such efficiency was actually reached in later full scale operation.

The Interlake Research Department undertook another program in which they studied the means by which cyanide could be treated by oxidation. In full scale research performed at Interlake's Toledo Plant, it was found that the free falling of water through an air current resulted in an effective reduction in the cyanide concentration. We do not have definitive results of these earlier tests, however parallel tests of a quantitative type were conducted at the Chicago and Toledo Coke plants in July, 1971. Results of these tests are tabulated in Appendix B. Although the effectiveness of this aeration treatment was erratic, it appeared that about 45 percent of the cyanide could be removed from coke plant waters.

The design of the Chicago recirculating system was based on bringing the scrubber water to a clarifier, flocculation with a polyelectrolyte, settling of the solids and passage of the overflow through a cooling tower. This practice promised to effectively suppress the build-up of cyanide concentration in the recycle system.

4. What effect would polyelectrolytes have in improving sedimentation efficiency in the clarifiers?

It would be logical to expect that the level of suspended solids in the clarifier effluent would build up gradually on a recycle type operation. This idea is based on the principle that finer sized particles would not be captured in the clarifier. Such particles would theoretically not have enough time to settle in the clarifier and would pass into the overflow effluent. On each pass through the gas cleaner, more small particles would be added to the wash water, and the concentration of particles would steadily increase. It is probable that such a small particle build-up would be encountered, if steps were not taken to induce optimum flocculation of these particles. It is suspected that the particles undergo some type of self-flocculation at higher concentration, and thus the small particle solids removal capability of a clarifier is increased on recycle. In addition to the above mentioned "self-flocculation", it is desirable that solids be encouraged to precipitate to the maximum degree possible, in order to reduce the possibility of plugging or pipe restriction anywhere in the system, and to minimize the loss of suspended solids in the blow-down. Improved sedimentation efficiency is important to the success of the recycle system and the effectiveness of polyelectrolytes for this service was hopefully expected, but unknown. This factor was, therefore, one of the questionable features of the recirculation system.

SECTION V

DESIGN OF RECIRCULATING SYSTEM

The arrangement of the original Chicago Plant Blast Furnace gas cleaning system, Sinter Plant fume collecting system and the associated waste water handling systems has been briefly mentioned in earlier sections of this report, but it is appropriate, before launching into a description of the redesign of this system, to describe in some detail, the system as it existed before the recirculating system was built. A simplified schematic diagram of the system was shown in Figure 6.

Secondary cleaning of blast furnace gas from both "A" and "B" furnaces is performed in high-energy wet scrubbers. "A" furnace is equipped with a Research Cottrell Louver-type variable-orifice scrubber, a unit which was designed to meet Interlake's specifications and which has been extremely successful in reducing maintenance of the gas-cleaning system. "B" furnace uses a variable-throat venturi scrubber as manufactured by Chemico. At each furnace, the high-energy scrubber is followed by a Chemico centrifugal water separator, and then by a counter-current spray tower or gas cooler. The spray tower's principal function is cooling of the gas. The "A" furnace gas system also includes a moisture eliminator mounted at the top of the spray tower, to minimize entrainment of moisture in the gas. The "B" furnace gas system has no moisture eliminator.

Gas scrubbing water was withdrawn from the plant water system, with booster pumps for that portion which was fed to high pressure sprays. Discharge water from the scrubbers was collected in the centrifugal separators and fed to the 90-foot diameter primary clarifier located in the vicinity of the blast furnaces. Effluent water from the spray tower was originally, because of its relative cleanliness, discharged directly to the Calumet River, thus reducing the hydraulic load on the clarifier. Studies of gas cleaning system discharge waters, with measurements taken daily over a period of more than 10 years, indicated that the average dust loading of the spray tower discharge water was less than one tenth that of the scrubber water.

As furnace production was increased and as the need for cleaner effluents to the river became evident, the spray tower effluents, even though relatively clean, were also directed to the clarifier.

Before construction of the new sinter plant at the south end of the Chicago Plant, disc-type Oliver filters, located in the old sinter plant adjacent to the primary clarifier, produced a filter cake from the clarifier underflow. When the new sinter plant was built in 1960, it was decided that it would be advantageous to consolidate the filtering equipment at the new sinter plant. Under-flow from the blast-furnace clarifier was pumped at a relatively low solids content (5 to 10% solids) to a 40-foot diameter sinter plant clarifier. During the past eleven years, the blast furnace flue dust production has been drastically reduced and, as shown in the figures of Table 7, the suspended solids content in the blast furnace clarifier underflow has correspondingly been reduced from the original 5 - 10% solids.

The sinter plant and its auxiliaries are provided with two dust collecting systems. System "A" is ducted to pick up fines and fumes at the following points in or near the main building of the sinter plant:

Sinter Machine Discharge Hood
Hot Sinter Feeder
Hot Sinter Screen
Hot Fines Feeder
Hot Fines Surge Bin
Cold Fines Feeder
Hot Fines Conveyor
Various Conveyor Transfer Points

Capacity of the "A" system fan is 90,000 C.F.M.

System "B" picks up from the following points in the vicinity of the sinter screening station:

Sinter Cooler Discharge Hood
Primary Sinter Screens
Secondary Sinter Screens
Conveyor Loading Points and Discharges

Capacity of the "B" system fan is 53,000 C.F.M.

Each system includes ducts, dampers for system balance, a wet scrubber and a fan. Although the scrubbers were originally equipped with Peabody impingement trays, continual plugging of the cleaning elements occurred, and the scrubbers were eventually converted to spray towers. Sludge draining from the "A" and "B" system scrubbers flowed by gravity to the sinter plant clarifier.

The sinter plant clarifier received the effluent from the sinter plant dedusting systems as well as the underflow from the blast furnace clarifier. Underflow from the sinter plant clarifier was pumped to the disc-type filters located within the sinter plant. The filter cake produced here dropped onto a belt conveyor which could feed the cake directly to the sinter machine feed conveyor or to a railroad car for alternate disposal at a storage area.

Design of the recirculating system was initiated in 1968. In view of their knowledge of our Chicago Plant feed water and waste water systems, and their reputation for expertise in the field of waste treatment, Stanley Consultants were retained to assist Interlake in the engineering of the blast furnace and sinter plant gas cleaning and dust collecting water recycling system.

Several differences do exist between the blast furnace and sinter plant systems. The blast furnace system is not equipped with a filter for removal of solids from the primary clarifier underflow. Instead, that underflow is pumped to a sludge thickener or concentrator at the sinter plant. As stated earlier in this report, this consolidates the filtering equipment at a location convenient to the processing of the solids. As a result of a cooperative study, Flow Schematic CA-3253, shown in Figure 9 was developed. This diagram shows both the blast furnace and the sinter plant systems and their interconnections. Note that each system performs the same basic functions. The process water becomes dust laden and warm in the gas cleaning units. The dirty, heated water is then cleaned through the settling action in a separator and is aerated and cooled in a cooling tower. The treated water is then re-used in the wet scrubber units.

Duplicate underflow lines are provided from the blast furnace system to the sinter plant system. One of these lines is available as a stand-by underflow line, but it was also intended to serve as a means of taking blowdown from the sinter plant system for disposal in the blast furnace area. One possibility considered was the disposal of blowdown as slag quenching water at the "A" and "B" furnace slag pits.

The existing secondary clarifier at the sinter plant was changed to perform only as a primary clarifying unit with underflow being pumped to the sludge thickener. The sludge thickener concentrated the slurries received from the blast furnace and sinter plant clarifiers and pumped a high solids content sludge to the disc filters.

In order to portray the recycle systems in the various stages of change and development which occurred during start-up, debugging and refinement of the systems, a series of simplified flow diagrams, Figure 10 through 15 has been prepared. Duplicate pumping, piping, and valving equipment has been omitted from these diagrams, for ease of explanation and understanding.

Figure 10 diagrams the recycle systems as they were initially installed. Dark lines outline all new equipment and piping. Changes from the systems as originally developed in conjunction with Stanley Consultants included the following items.

Blast Furnace Clarifier drains to the sewer or river were eliminated.

Stove cooling water and condensate drains to

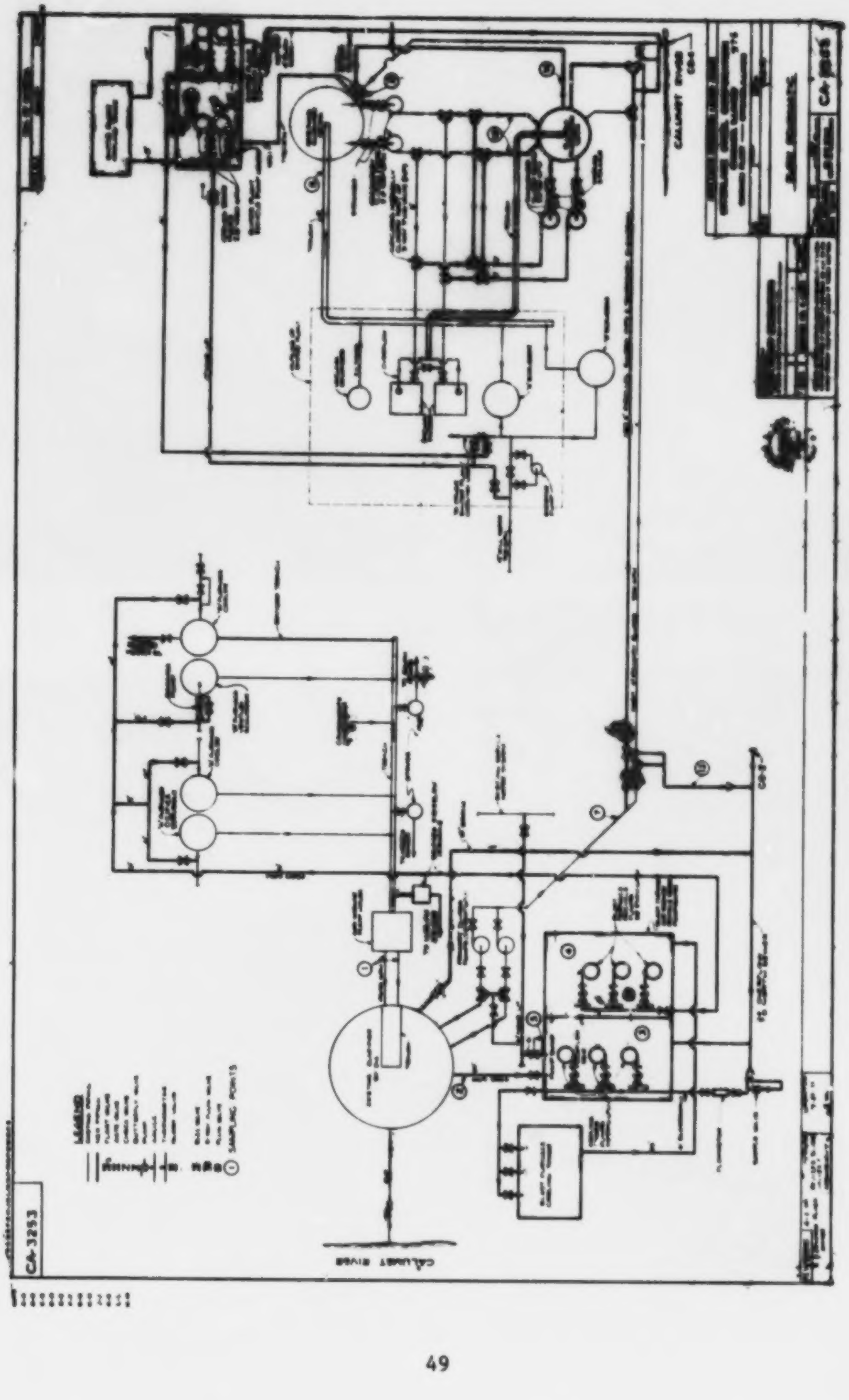
CA-3253
LEGEND
SAMPLING POINTS
CALUMET RIVER

Fig. 9 - Flow Schematic

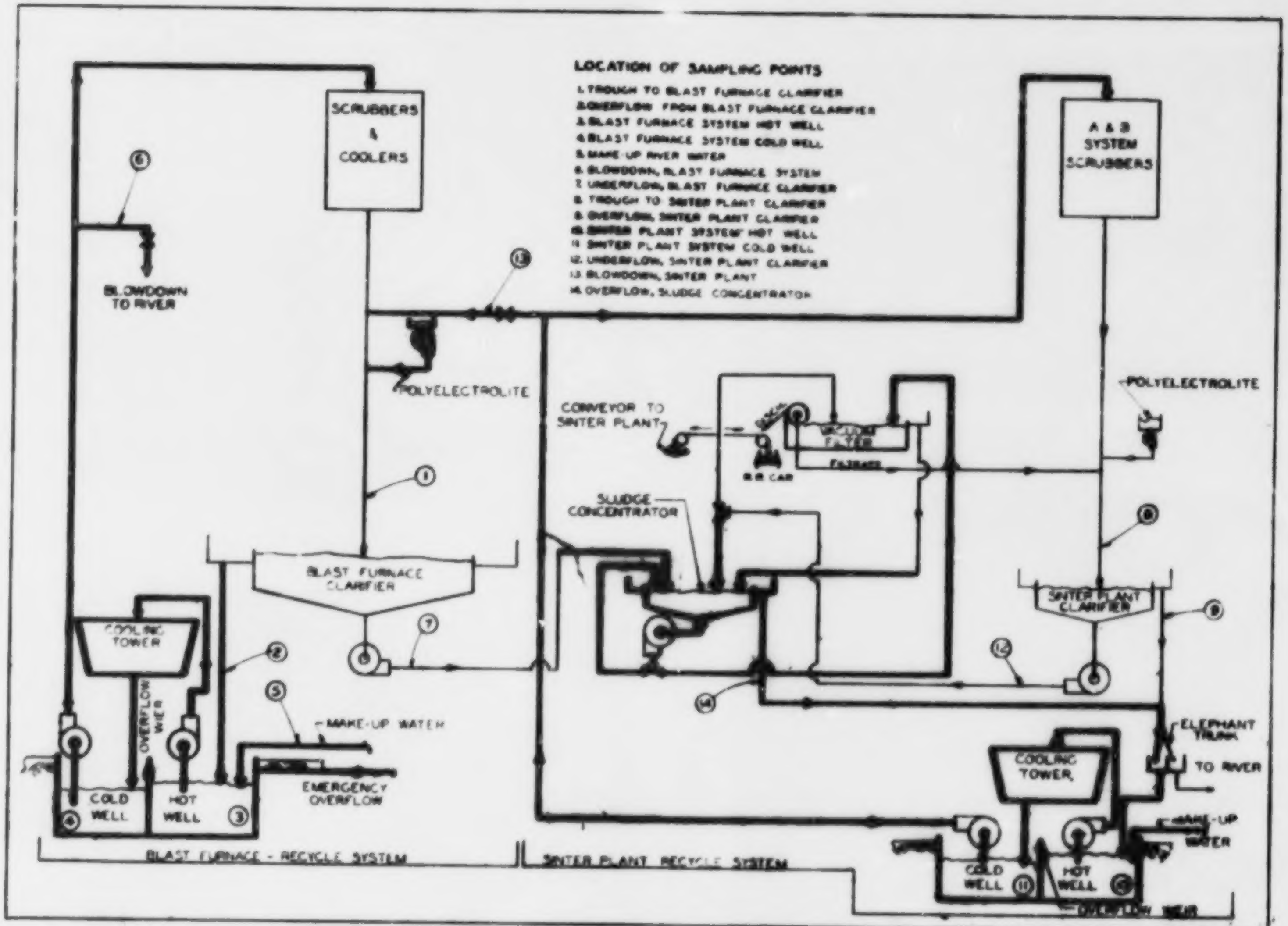
LOCATION OF SAMPLING POINTS
1. TROUGH TO BLAST FURNACE CLARIFIER
2. OVERFLOW FROM BLAST FURNACE CLARIFIER
3. BLAST FURNACE SYSTEM HOT WELL
4. BLAST FURNACE SYSTEM COLD WELL
5. MAKE-UP RIVER WATER
6. BLOWDOWN, BLAST FURNACE SYSTEM
7. UNDERFLOW, BLAST FURNACE CLARIFIER
8. TROUGH TO SINTER PLANT CLARIFIER
9. OVERFLOW, SINTER PLANT CLARIFIER
10. SINTER PLANT SYSTEM HOT WELL
11. SINTER PLANT SYSTEM COLD WELL
12. UNDERFLOW, SINTER PLANT CLARIFIER
13. BLOWDOWN, SINTER PLANT
14. OVERFLOW, SLUDGE CONCENTRATOR
SCRUBBERS & COOLERS
A & B SYSTEM SCRUBBERS
BLOWDOWN TO RIVER
POLYELECTROLITE
POLYELECTROLITE
CONVEYOR TO SINTER PLANT
VACUUM FILTER
FILTRATE
R.R. CAR
SLUDGE CONCENTRATOR
BLAST FURNACE CLARIFIER
SINTER PLANT CLARIFIER
COOLING TOWER
OVERFLOW WEIR
MAKE-UP WATER
EMERGENCY OVERFLOW
COLD WELL
HOT WELL
COOLING TOWER
ELEPHANT TRUNK
TO RIVER
MAKE-UP WATER
COLD WELL
HOT WELL
OVERFLOW WEIR
BLAST FURNACE - RECYCLE SYSTEM
SINTER PLANT RECYCLE SYSTEM
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Fig. 10 - Blast Furnace & Sinter Plant Scrubber Water Recycle Systems - As Initially Installed

the recycle system were disconnected. Water from these sources was redirected to sewers.

Overflow to the north sewer, CO-2, of untreated gas cleaning water was eliminated. This overflow had taken place from a manhole connected to the trench carrying dirty water to the gas washer pump house (shown on figure 9).

Polyelectrolyte additive system was added at blast furnace clarifier.

Blowdown from the sinter plant recycle system which was first shown as discharging into the north sewer, CO-2, was redirected to the blast furnace clarifier.

SECTION VI

SYSTEM OPERATION - START-UP AND REFINEMENT

The blast furnace recycle system as shown in Figure 10 went into operation on October 31, 1969. The sinter plant system started a few days later.

The first seven days were spent phasing the systems in, one section at a time. During this period, there was 24-hour supervision by Engineering and Environmental Control representatives. The time was also used to train plant operating personnel.

Neither recycle system was introduced into the production cycle until it had been run under operating conditions. This was accomplished by maintaining a supply of mill water to the blast furnace gas cleaning and sinter plant dust collection systems, and running the effluent directly to the river (equivalent to 100 percent blow-down). This allowed the testing of all equipment and balancing of the system, without interruption of blast furnace and sinter plant production. All piping tie-ins had been completed during the construction phase, using scheduled maintenance shutdowns at the blast furnace and sinter plant. There were no curtailments nor reduced production periods associated with the phase-in of the recycle system.

In adopting the use of recycle systems, the primary objective was to achieve conformity with established effluent standards. The ultimate goal was complete elimination of all effluents to the Calumet River. When the recycle systems were designed, it was thought that effluent standards could be met by reducing the effluent to only a small flow of blow-down (approximately 2%). Due to the high concentration of contaminants in the system, the blow-down quality could not be tolerated in the river and it was decided that blow-down from the systems should normally be discharged to a sanitary sewer instead of the river. Emergency overflows to the river were sealed off. These piping revisions were made, and system operation changed as shown in Figure 11.

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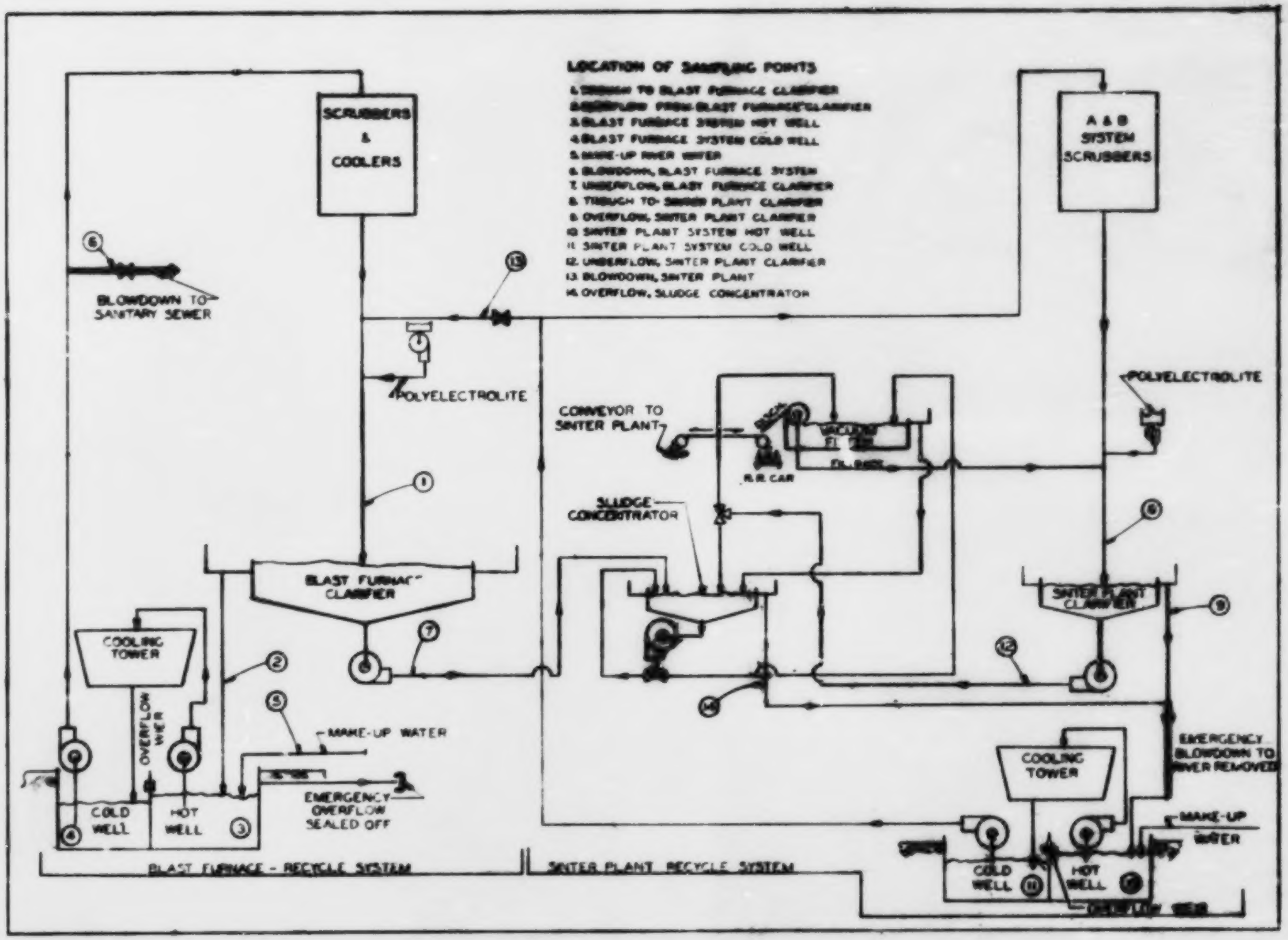
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6. BLOWDOWN, BLAST FURNACE SYSTEM
7. UNDERFLOW, BLAST FURNACE CLARIFIER
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10. SINTER PLANT SYSTEM HOT WELL
11. SINTER PLANT SYSTEM COLD WELL
12. UNDERFLOW, SINTER PLANT CLARIFIER
13. BLOWDOWN, SINTER PLANT
14. OVERFLOW, SLUDGE CONCENTRATOR
SCRUBBERS & COOLERS
A & B SYSTEM SCRUBBERS
BLOWDOWN TO SANITARY SEWER
POLYELECTROLITE
POLYELECTROLITE
CONVEYOR TO SINTER PLANT
VACUUM FILTER
R.R. CAR
SLUDGE CONCENTRATOR
BLAST FURNACE CLARIFIER
SINTER PLANT CLARIFIER
COOLING TOWER
OVERFLOW WIER
COLD WELL
HOT WELL
MAKE-UP WATER
EMERGENCY OVERFLOW SEALED OFF
COOLING TOWER
EMERGENCY BLOWDOWN TO RIVER REMOVED
MAKE-UP WATER
COLD WELL
HOT WELL
OVERFLOW WEIR
BLAST FURNACE - RECYCLE SYSTEM
SINTER PLANT RECYCLE SYSTEM
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Fig. 11 - Blast Furnace & Sinter Plant Scrubber Water Recycle Systems - Modified to Discharge Blowdown into Sanitary Sewers

Once the system achieved the designed operating status, six major problems developed. These problems occurred and corrective measures were taken as described in the following paragraphs:

1. Hydraulic Balance

   It became evident that unaccounted for water was infiltrating the system, making it impossible for the sanitary sewer to accommodate all blow-down, and requiring some blow-down to the river. Each time the blow-down to the river was shut off there would be a constant pick-up of water level in the blast furnace system, and after 6 to 8 hours time lag, the high-water alarm would go off. Then the blow-down had to be reopened to the river. When the system was designed, it was thought that all major heat-exchange water systems were divorced from the system, leaving only process contaminated water going to the recycle systems. With the recycle system integrated with the old effluent system, small amounts of water were evidently being discharged from a number of sources which did not show on current plant drawings. It is estimated that 800 to 1000 GPM of water were infiltrating the system. Because of the underground location of these infiltration points, it was difficult and time-consuming to identify and eliminate them. The sources which were discovered included stove valve cooling water, unknown water supply cross-connections, pump gland water and water from shut-off valves. By March, 1970, the system was isolated from exterior water sources, blow-down to the river was shut off and the systems were in balance. There has been no need to blow-down to the river, to relieve high water situations, since that time.

   Although the original scheme was to blow-down the blast furnace recycle system after the water had passed through the cooling tower, in order to send minimal cyanide content to the sanitary sewer, this pattern of flow did not produce good hydraulic balance, in that water needed for gas cleaning and cooling was being taken from the scrubber water supply system.

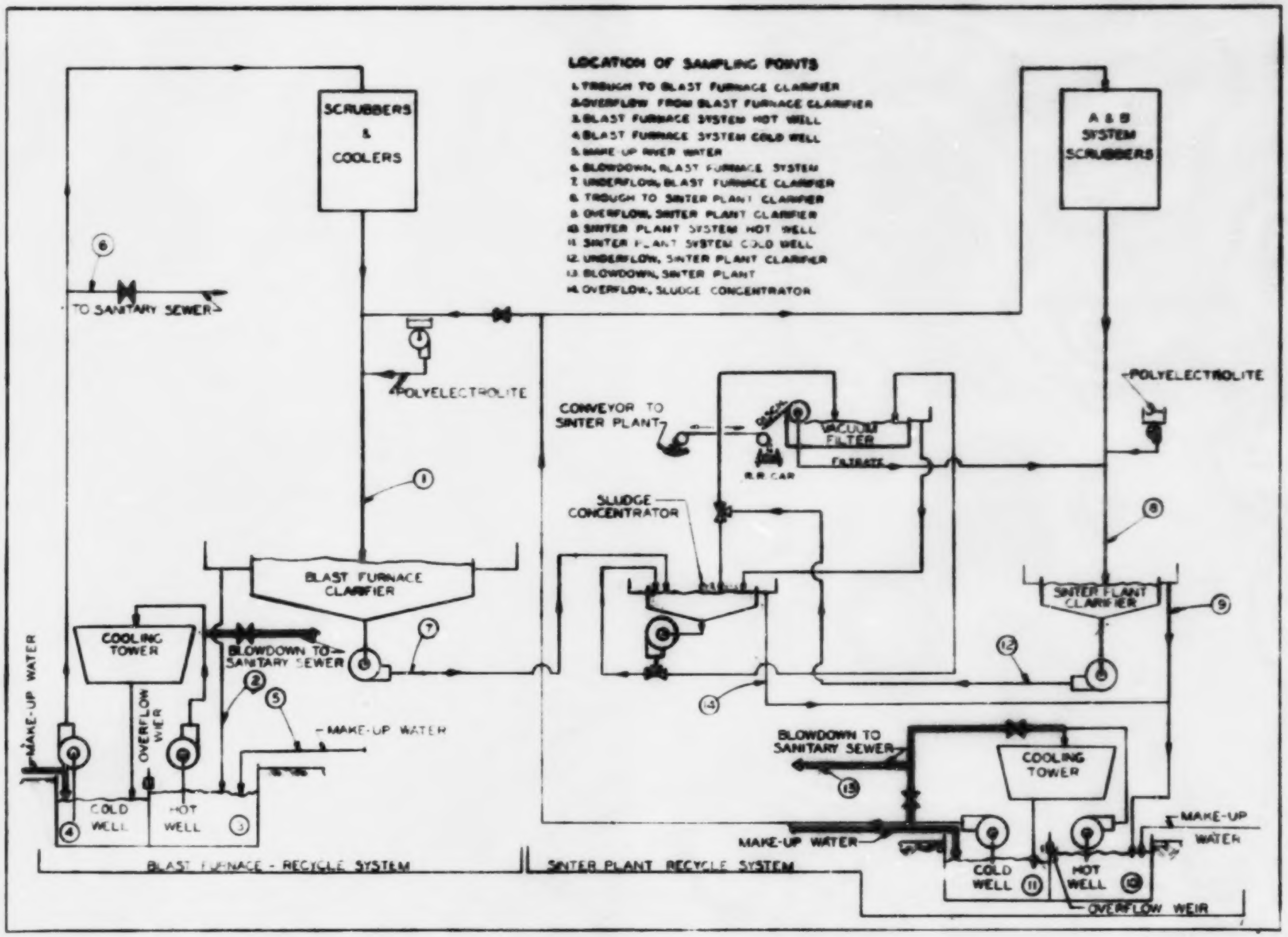
The systems were therefore modified, as shown in Figure 12, to allow blow-down from either the hot-well or cold-well pumps. Provisions were also made to add make-up water in both hot wells and cold wells. With the modified piping, the normal mode of operation called for blow-down from the hot well (the clarifier overflow basin at the sinter plant) and make-up in the cold well. These changes relieved the load on both cooling towers and resulted in satisfactory hydraulic balance in the system.

As mentioned earlier, one possibility originally considered was the disposal of blow-down as slag quenching water at the "A" and "B" furnace slag pits. Due to the intermittent nature and high requirements of this usage, approximately 1500 G.P.M. for 4 hours, 3 times a week, this method of disposal was never attempted for fear of throwing the system out of balance.

2. Sludge Concentrator

The sludge concentrator had been designed to concentrate slurry from the blast furnace and sinter plant clarifier underflows and vacuum filter over-flow.

The concentrated sludge was then to be pumped to the vacuum filters, with sludge concentrator overflow returned as cleaned water to the recycle system. As operated in this manner, the overflow from the sludge concentrator was not adequately clarified. It was not unusual to experience suspended solids contents of over 400 ppm. Eventually the hot well filled with sludge to the point that it had to be pumped out and shoveled clean. Water sprays at the cooling tower also plugged.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2. OVERFLOW FROM BLAST FURNACE CLARIFIER
3. BLAST FURNACE SYSTEM HOT WELL
4. BLAST FURNACE SYSTEM COLD WELL
5. MAKE-UP RIVER WATER
6. BLOWDOWN, BLAST FURNACE SYSTEM
7. UNDERFLOW, BLAST FURNACE CLARIFIER
8. TROUGH TO SINTER PLANT CLARIFIER
9. OVERFLOW, SINTER PLANT CLARIFIER
10. SINTER PLANT SYSTEM HOT WELL
11. SINTER PLANT SYSTEM COLD WELL
12. UNDERFLOW, SINTER PLANT CLARIFIER
13. BLOWDOWN, SINTER PLANT
14. OVERFLOW, SLUDGE CONCENTRATOR
SCRUBBERS & COOLERS
A & B SYSTEM SCRUBBERS
TO SANITARY SEWER
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OVERFLOW WIER
MAKE-UP WATER
COLD WELL
HOT WELL
BLOWDOWN TO SANITARY SEWER
COOLING TOWER
MAKE-UP WATER
MAKE-UP WATER
COLD WELL
HOT WELL
OVERFLOW WEIR
BLAST FURNACE - RECYCLE SYSTEM
SINTER PLANT RECYCLE SYSTEM
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Fig. 12 - Blast Furnace & Sinter Plant Scrubber Water Recycle Systems - Modified to Permit Make-up & Blowdown Either Before or After Cooling Tower

To improve this situation, it was necessary to lighten the load on the concentrator by reducing the flow of sludge to this unit, as shown in Figure 13. This was done by feeding only the blast furnace clarifier underflow to this unit, and sending the sinter plant clarifier underflow directly to the vacuum filter. Filter overflow was directed to the sinter plant clarifier to further reduce the hydraulic load on the sludge concentrator. This accomplished only partial relief from the problem, and it was decided that the concentrator would be abandoned. Piping was rearranged to direct blast furnace clarifier underflow to the sinter plant clarifier, as it had been before installation of the recirculating system. Figure 14 shows this mode of operation. The sludge concentrator has been retained as a spare unit for temporary use during maintenance of the sinter plant clarifier.

3. Coarse Particulates

Although certain changes, as described in earlier paragraphs had to be made to improve operations, the system operated in a satisfactory manner from March to July, 1970. On July 17th, a serious emergency occurred. Both underflow lines from the blast furnace clarifier plugged and the clarifier rake stalled. All efforts to unplug the underflow lines failed, and the decision was made to shut both furnaces down, pump the clarifier water and sludge into the ore yard, and free the rake and underflow lines. Drainage of the ore yard is by seepage and evaporation only. The entire clean-out was accomplished in approximately 24 hours. No mechanical failures were discovered, but the slurry removed from the underflow lines contained a large amount of very coarse particulate matter (minus ¼-inch, plus 100 mesh). The evident reason for the failure was the high settling rate of these coarse, high density sludge particles which eventually completely plugged the lines. This, in turn, caused a building up of solids in the bottom of the clarifier

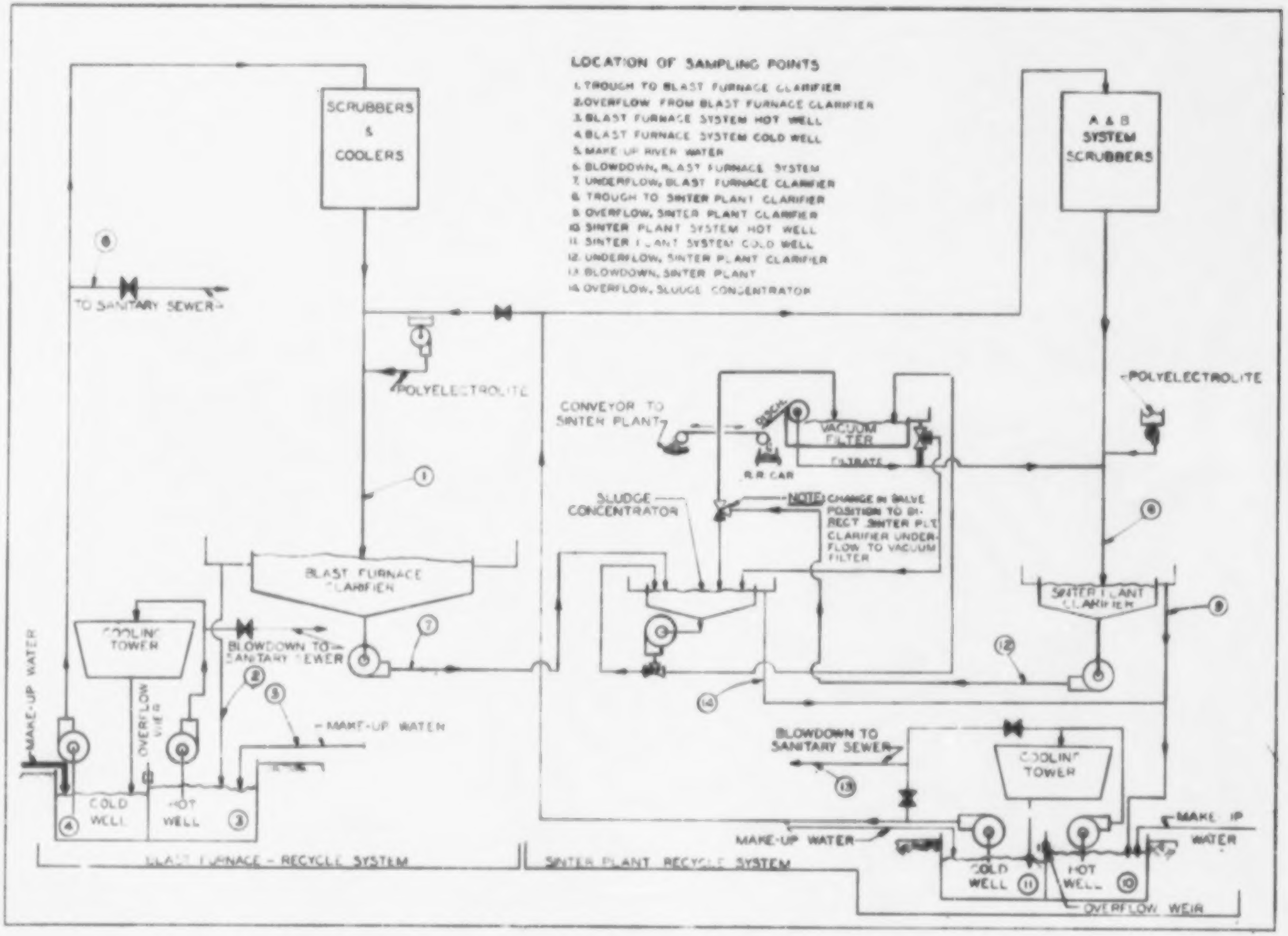
LOCATION OF SAMPLING POINTS
1. TROUGH TO BLAST FURNACE CLARIFIER
2. OVERFLOW FROM BLAST FURNACE CLARIFIER
3. BLAST FURNACE SYSTEM HOT WELL
4. BLAST FURNACE SYSTEM COLD WELL
5. MAKE UP RIVER WATER
6. BLOWDOWN, BLAST FURNACE SYSTEM
7. UNDERFLOW, BLAST FURNACE CLARIFIER
8. TROUGH TO SINTER PLANT CLARIFIER
9. OVERFLOW, SINTER PLANT CLARIFIER
10. SINTER PLANT SYSTEM HOT WELL
11. SINTER PLANT SYSTEM COLD WELL
12. UNDERFLOW, SINTER PLANT CLARIFIER
13. BLOWDOWN, SINTER PLANT
14. OVERFLOW, SLUDGE CONCENTRATOR
SCRUBBERS & COOLERS
A & B SYSTEM SCRUBBERS
6
TO SANITARY SEWER
POLYELECTROLITE
POLYELECTROLITE
1
8
CONVEYOR TO SINTER PLANT
VACUUM FILTER
FILTRATE
R.R. CAR
SLUDGE CONCENTRATOR
NOTE: CHANGE IN VALVE POSITION TO DIRECT SINTER PLT CLARIFIER UNDERFLOW TO VACUUM FILTER
BLAST FURNACE CLARIFIER
SINTER PLANT CLARIFIER
9
COOLING TOWER
MAKE-UP WATER
OVERFLOW WIER
BLOWDOWN TO SANITARY SEWER
7
2
5
MAKE-UP WATER
COLD WELL
HOT WELL
4
3
12
14
BLOWDOWN TO SANITARY SEWER
13
COOLING TOWER
MAKE-UP WATER
MAKE UP WATER
COLD WELL
11
HOT WELL
10
OVERFLOW WEIR
BLAST FURNACE - RECYCLE SYSTEM
SINTER PLANT RECYCLE SYSTEM

Fig. 13 - Blast Furnace & Sinter Plant Scrubber Water Recycle Systems - Modified to Reduce Load on Sludge Concentrator

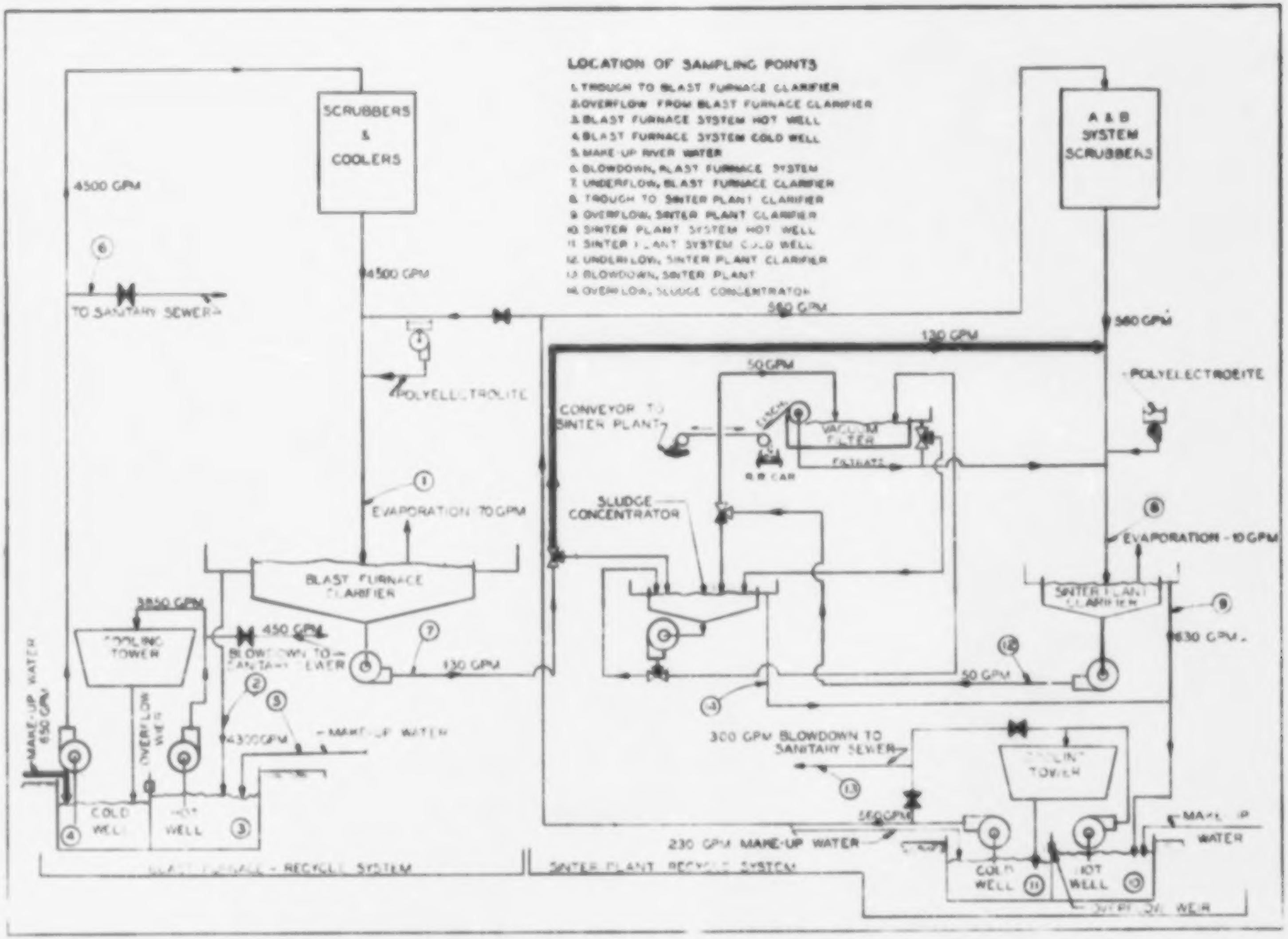
LOCATION OF SAMPLING POINTS
1. TROUGH TO BLAST FURNACE CLARIFIER
2. OVERFLOW FROM BLAST FURNACE CLARIFIER
3. BLAST FURNACE SYSTEM HOT WELL
4. BLAST FURNACE SYSTEM COLD WELL
5. MAKE-UP RIVER WATER
6. BLOWDOWN, BLAST FURNACE SYSTEM
7. UNDERFLOW, BLAST FURNACE CLARIFIER
8. TROUGH TO SINTER PLANT CLARIFIER
9. OVERFLOW, SINTER PLANT CLARIFIER
10. SINTER PLANT SYSTEM HOT WELL
11. SINTER PLANT SYSTEM COLD WELL
12. UNDERFLOW, SINTER PLANT CLARIFIER
13. BLOWDOWN, SINTER PLANT
14. OVERFLOW, SLUDGE CONCENTRATOR
SCRUBBERS & COOLERS
A & B SYSTEM SCRUBBERS
4500 GPM
4500 GPM
TO SANITARY SEWER
POLYELECTROLITE
EVAPORATION 70 GPM
BLAST FURNACE CLARIFIER
3850 GPM
COOLING TOWER
450 GPM
BLOWDOWN TO SANITARY SEWER
130 GPM
4300 GPM
MAKE-UP WATER
MAKE-UP WATER 650 GPM
OVERFLOW WEIR
COLD WELL
HOT WELL
BLAST FURNACE - RECYCLE SYSTEM
560 GPM
560 GPM
130 GPM
50 GPM
CONVEYOR TO SINTER PLANT
VACUUM FILTER
FILTRATE
R.R. CAR
SLUDGE CONCENTRATOR
POLYELECTROLITE
EVAPORATION - 10 GPM
SINTER PLANT CLARIFIER
630 GPM
50 GPM
300 GPM BLOWDOWN TO SANITARY SEWER
COOLING TOWER
560 GPM
230 GPM MAKE-UP WATER
MAKE-UP WATER
COLD WELL
HOT WELL
OVERFLOW WEIR
SINTER PLANT RECYCLE SYSTEM

Fig. 14 - Blast Furnace & Sinter Plant Scrubber Water Recycle Systems - Modified to Eliminate Flow to Sludge Concentrator

to the point that the rake drive load limits were exceeded. Since the experience in July, 1970, there have been several occasions when the slurry has become very coarse and dense, but changes in operating procedures prevented any major shutdowns until June, 1971. There are two underflow lines and pumps from the blast furnace system clarifier, one on stream and one on stand-by. Since July, 1970, the pump on stand-by has been given prompt corrective and preventive maintenance so that it is ready for immediate use when needed. If there is evidence of plugging, both underflow pumps are immediately put on stream. Prior to July, 1970, there were periods when both underflow pumps were shut down for a short time. Now one pump is kept running at all times.

When the recycle systems were built, a back-up pump and transmission line were provided for every vulnerable part of the system, to insure uninterrupted operation. Our experience of July 17, 1970 demonstrated the vulnerability of the clarifier and the need for a spare. Interlake is presently in the process of installing a second clarifier for the blast furnace system. This second unit will be large enough to handle all the gas cleaning water during repairs or failure of the first clarifier. Figure 15 shows a diagram of the system with a stand-by clarifier. Unfortunately, another emergency shut down of the clarifier, and consequently the blast furnaces, occurred on June 28th, 1971. The cause was indeterminate, but probably was the same as that of the earlier failure.

4. Pump and Valve Maintenance

This problem was evident within a few weeks after start-up, and has been a continual one. There are a total of 23 pumps and over 100 valves associated with the two systems. Maintenance of these units has been out of proportion to their size and number. The recycle and cooling tower pumps have been a constant

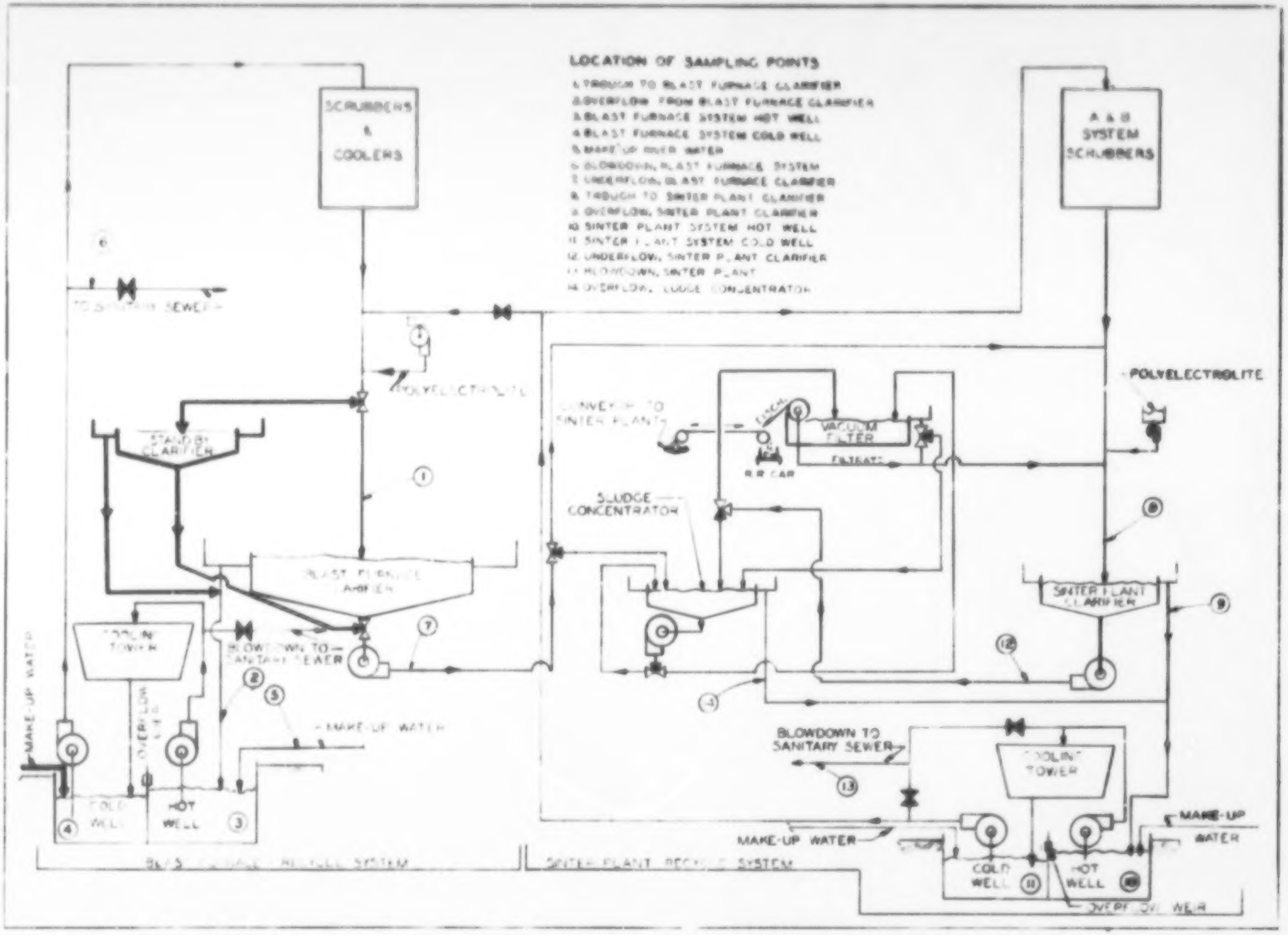
LOCATION OF SAMPLING POINTS
1. TROUGH TO BLAST FURNACE CLARIFIER
2. OVERFLOW FROM BLAST FURNACE CLARIFIER
3. BLAST FURNACE SYSTEM HOT WELL
4. BLAST FURNACE SYSTEM COLD WELL
5. MAKE-UP RIVER WATER
6. BLOWDOWN, BLAST FURNACE SYSTEM
7. UNDERFLOW, BLAST FURNACE CLARIFIER
8. TROUGH TO SINTER PLANT CLARIFIER
9. OVERFLOW, SINTER PLANT CLARIFIER
10. SINTER PLANT SYSTEM HOT WELL
11. SINTER PLANT SYSTEM COLD WELL
12. UNDERFLOW, SINTER PLANT CLARIFIER
13. BLOWDOWN, SINTER PLANT
14. OVERFLOW, SLUDGE CONCENTRATOR
SCRUBBERS & COOLERS
A & B SYSTEM SCRUBBERS
TO SANITARY SEWER
POLYELECTROLITE
STAND-BY CLARIFIER
BLAST FURNACE CLARIFIER
COOLING TOWER
OVERFLOW WEIR
BLOWDOWN TO SANITARY SEWER
MAKE-UP WATER
COLD WELL
HOT WELL
BLAST FURNACE RECYCLE SYSTEM
CONVEYOR TO SINTER PLANT
VACUUM FILTER
FILTRATE
R.R. CAR
SLUDGE CONCENTRATOR
SINTER PLANT CLARIFIER
POLYELECTROLITE
BLOWDOWN TO SANITARY SEWER
COOLING TOWER
MAKE-UP WATER
COLD WELL
HOT WELL
OVERFLOW WEIR
SINTER PLANT RECYCLE SYSTEM
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Fig. 15 - Blast Furnace & Sinter Plant Scrubber Water Recycle Systems - Modified with Stand-by Clarifier

source of bearing and drive shaft problems. One change made to alleviate this condition was a substitution of high pressure mill water for recycle system water in the bearing seals. This should eliminate scale or solids build-up in that area and reduce bearing failure.

Slurry pumps and valves have been a continual problem. We are continually investigating and trying new valves that will not plug with slurry when shut off. Our present thinking is that rubber pinch valves are the best for this service, however, it is axiomatic, in designing any sludge handling system, that dead sections of pipe in which solids can settle and consolidate must be eliminated or held to the minimum possible length. Three-way or four-way plug cocks which allow water flushing in various directions should be used wherever possible.

5. Control of Chemical Stability - Blast Furnace System

A build-up of scale or chemical formations in the blast furnace recycle system was not anticipated, and the only provisions originally made for pH control were those provided for the sinter plant system. It was, however, recognized that the rate of blow-down of both systems would have a significant effect on the chemical stability of the systems and that some measure of this chemical stability was a necessity.

Although the Ryznar Stability Index (a function of dissolved solids content, temperature, total alkalinity, calcium content, and pH) has been used primarily for boiler feed water evaluation, it was believed that this index would provide a dependable factor with which to monitor and evaluate the recycle system stability. In practice, a stability index of under 6 is indicative of a scaling tendency in a system, while an index over 6 shows the existence of corrosive conditions. See Appendix C for a more detailed discussion of stability indexes and their significance.

After the recycling systems had been placed in operation and had achieved a fair degree of hydraulic stability, the blow-down rate from the blast furnace system was established at 10%, while the blow-down rate from the sinter plant system was stabilized at 50%. These rates were set by determining the quantity of blow-down needed to obtain an acceptable Ryznar Stability Index in the recycle systems.

In order to prevent either corrosive or scaling conditions within the recycle system, it was our intention to maintain the stability index of the recycle system at 6. Without reliable continuous monitoring instrumentation (none is available), it is almost impossible to keep the recycle water system at a constant stability. The system was controlled manually, which procedure, in the early days of startup, resulted in a time lag of several hours before corrective action was taken to bring the stability index back to the desired value.

Figure 16 shows the stability index during the month of November, 1969, when the blast furnace system was first started. During the first month, the system was hydraulically overloaded, with an excessive amount of water being blown down. Approximately 50% of the total flow was diverted. This accounts for the stability index being greater than 6 during most of this period.

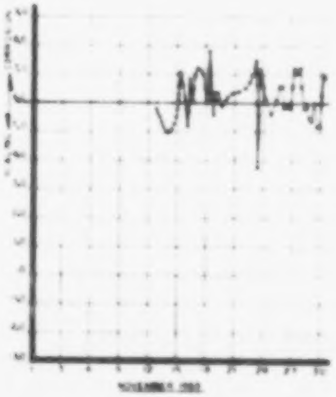

Fig. 16 Blast Furnace Water System Stability During Initial Operation with 50 Percent Blow-down Rate

Figures 17 through 19 show the blast furnace system stability index by month through December, 1970. During the first seven months, attempts were being made to tighten up the recycle system by reducing blow-down to a minimal quantity. This was necessary to effectively reduce the hydraulic load imposed upon the sanitary sewer. Reduction of the blow-down rate improved the hydraulic balance but had an undesirable side effect, namely: reduction of the stability index. Figure 17 indicates that the stability index moved downward into the scaling range, during this period, as the hydraulic balance was improved.

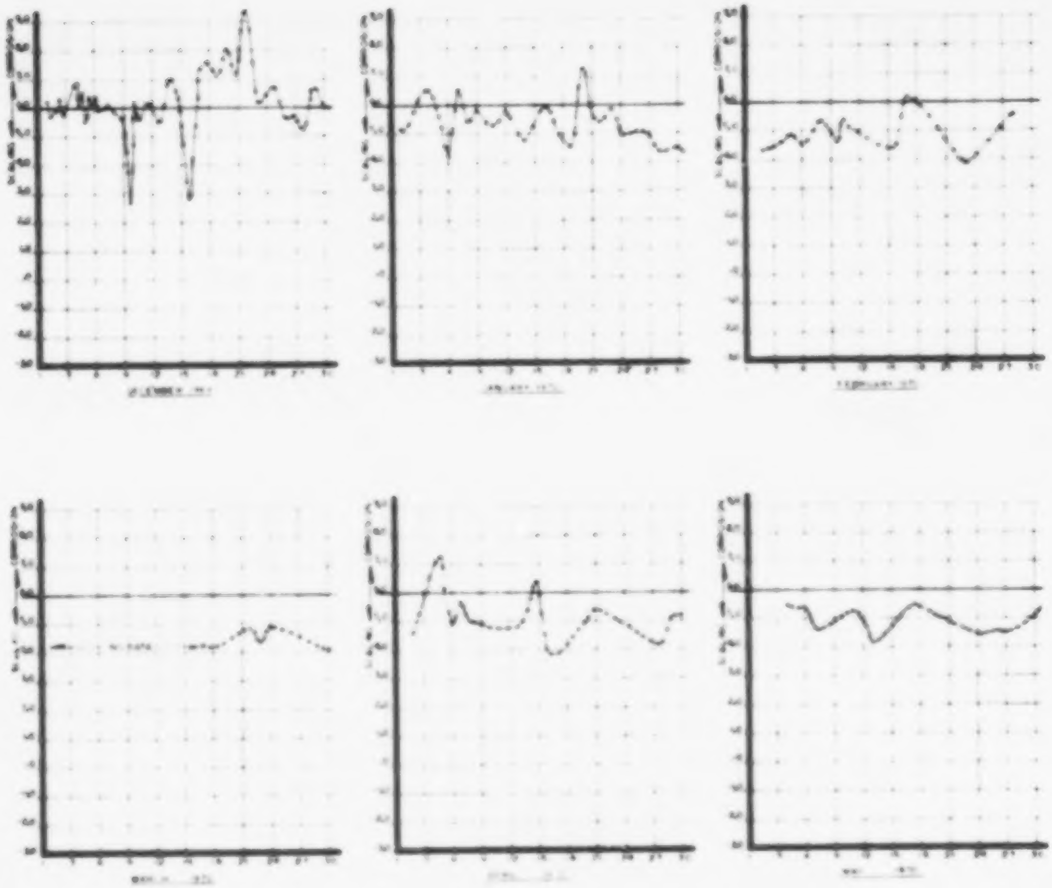

Fig. 17 Effect of Reduction of Blast Furnace Water System Blow-down Rate from 50 Percent to 10 Percent

As demonstrated in Figure 17, it became apparent that some method of control was needed to correct the depression of the stability index. As a corrective measure, the blow-down was periodically increased to about 25% for short periods of time (15 minutes), allowing more make-up water to be introduced (dilution). Figure 18 (June) shows that this concept worked, with resultant elevation of the stability index into a more desirable range.

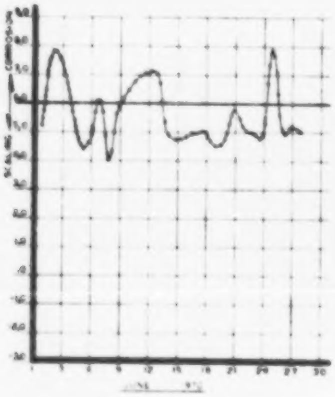

Fig. 18 Effects of Periodic Purging on Blast Furnace Water System Stability

Although the chemical stability was effectively improved, our sanitary sewer could not accommodate a blow-down of more than 25%. The practice had to be abandoned, and the stability index again moved into a lower range, as shown on Figure 19 (July, 1970 through December, 1970).

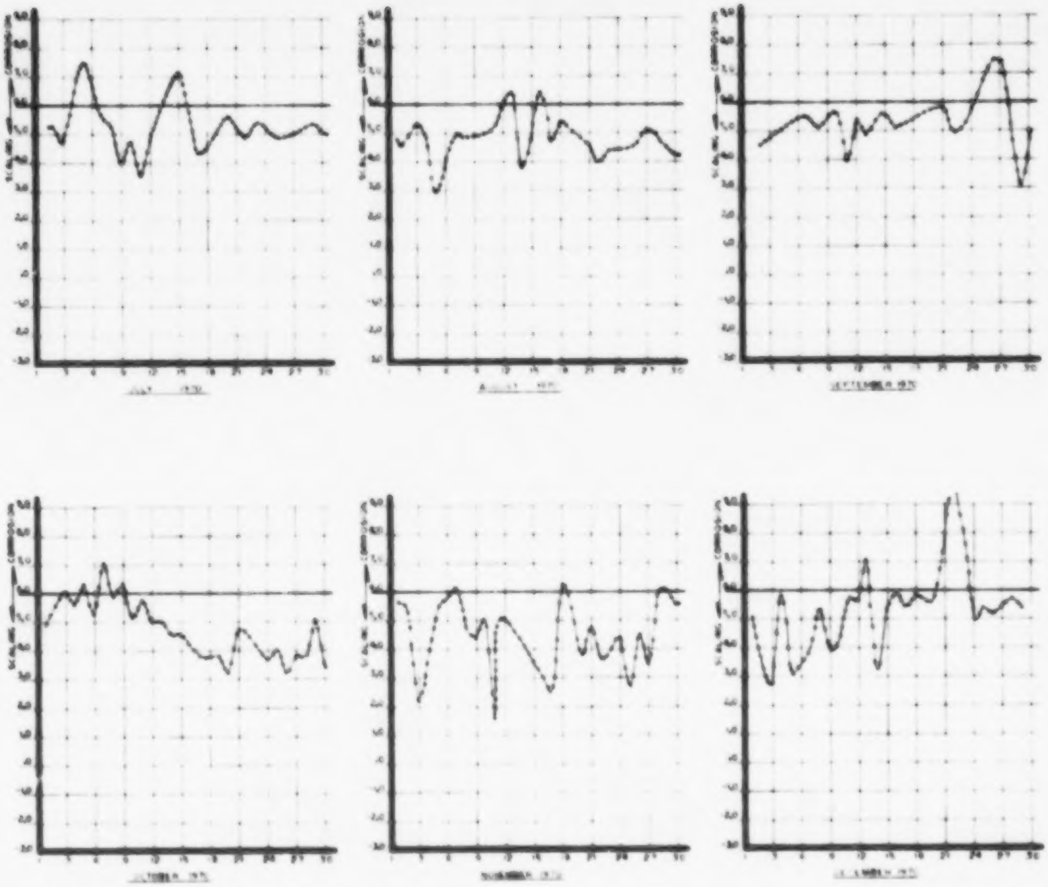

Fig. 19 Blast Furnace Water System Stability Under Scaling Conditions Prior to Acid Addition

By March, 1971, 3/4 of an inch of scale had formed in the recycle system piping. Flow meters were constantly being serviced, and eventually they became inoperable. At the rate the system was scaling, the blast furnace water system would have been plugged solid within a short period of time had not some corrective measure been taken. Acid addition for control of scaling was the obvious solution but its use would have to be carefully regulated. Using the Ryznar Index as a reference, the amount of acid needed to slowly dissolve the scale was calculated to be 200 gallons per day. Sulfuric acid was chosen because the by-product of its reaction, calcium sulfate, could be collected in the clarifier.

A metering pump and pH recorder were installed to feed acid into the cooling tower basin. On April 5, 1971, acid treatment began and has continued to date. 66° Baume sulphuric acid (35N) was fed into the system at a rate of about 10 tons per week. Figure 20 shows the Ryznar Index during the April, 1971 through July, 1971 period. As acid dissolved the scale, characteristics of the water changed, and regulation of acid additions was necessary. In the light of experience at the sinter plant, as described in sub-section 6, page 70, it was feared that the system might be overdosed; the acid feed rate, therefore, was limited to prevent a repetition of that experience. Periodic inspection indicated that the scale was being removed, even though the Index was below 6. Acid additions have been maintained since April, 1971.

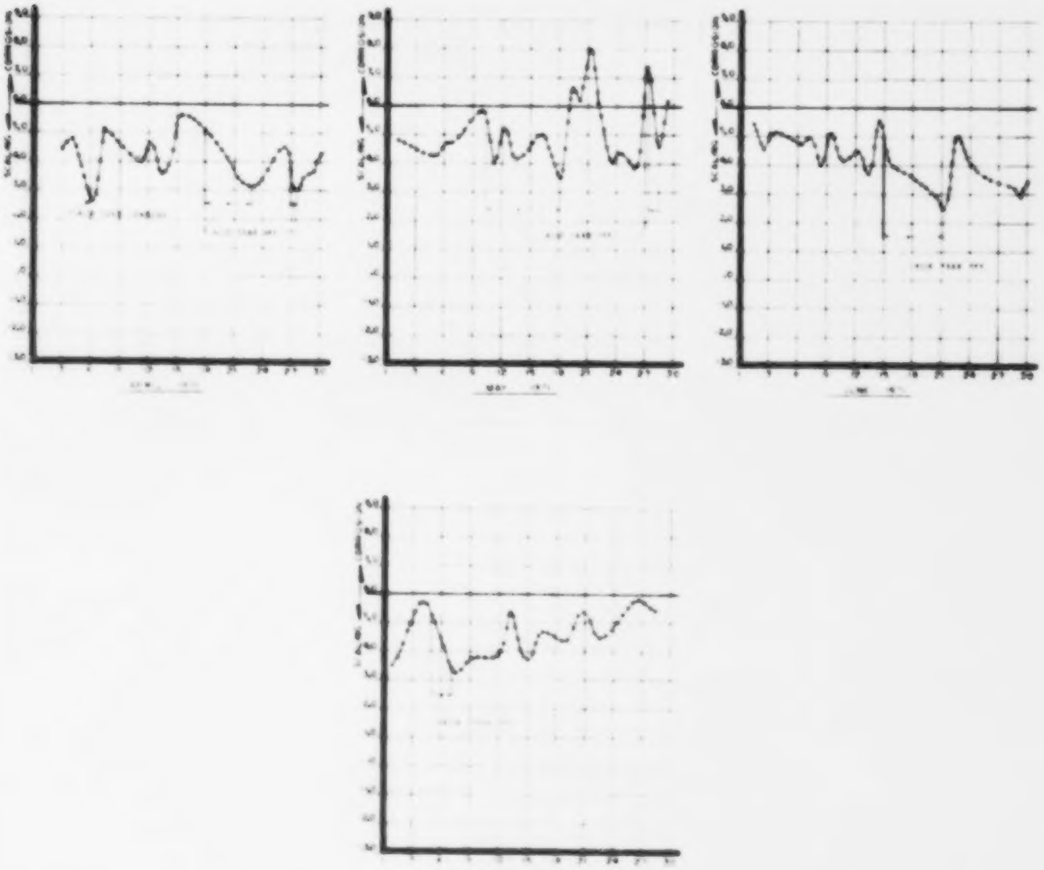

Fig. 20 Effect of Continuous Acid Addition on Blast Furnace Water System Stability

6. Control of Chemical Stability - Sinter Plant System

When the sinter plant produces a high basicity sinter, the lime and magnesia content of dusts collected in the sinter plant scrubbers is fairly high, and the water discharged from the scrubbers has a pH which always exceeds 12. It was known, from the beginning, that control of the stability index would be difficult, even with addition of hydrochloric acid. Figure 21 shows the range and variation of stability indexes in the sinter plant recycle system during the first six months of operation.

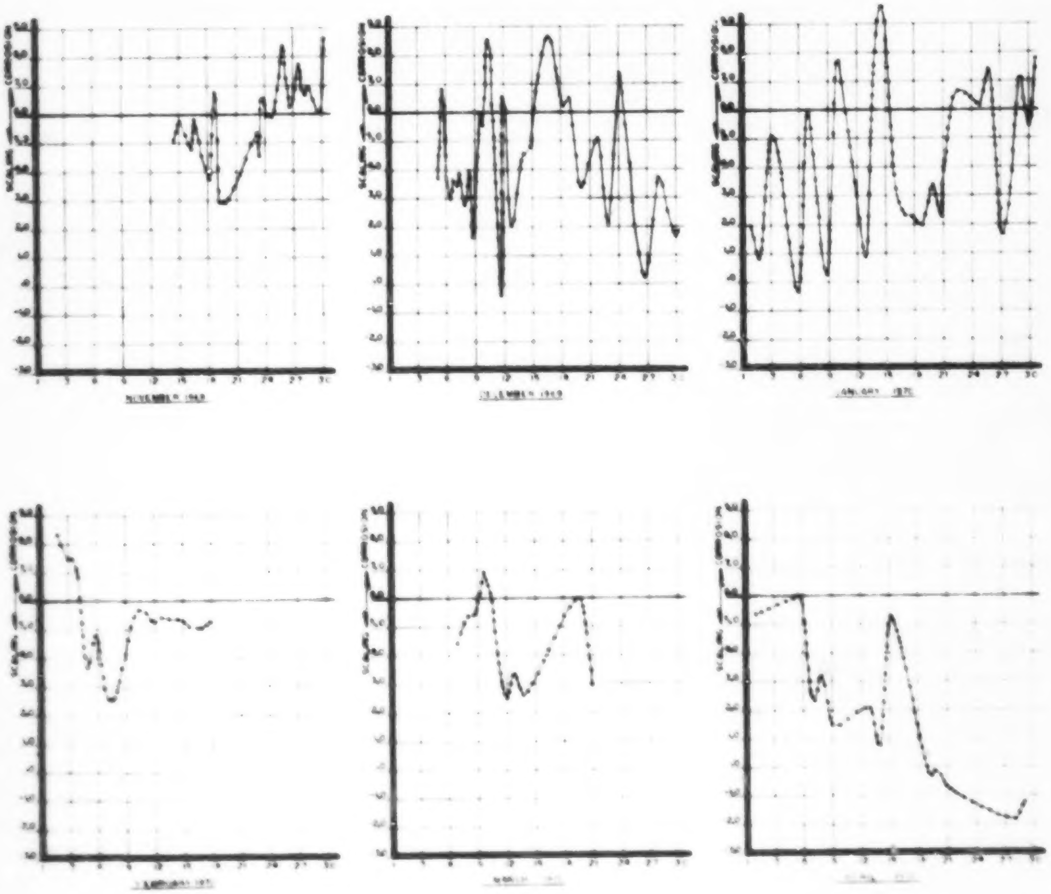

Fig. 21 Sinter Plant Water System Stability During Initial Operation with 25 Percent Blowdown Rate and Intermittent Acid Additions

As is evident in some of the above plots, the acid additions were effective in lowering the pH and, in turn, raising the stability index, but a stable condition was not obtainable with the manual control initially provided. Manual control was carried out in the following manner: The operator monitored the pH in the recycle system. When the pH exceeded 9, the operator increased acid flow rate to the clarifier overflow basin, adding about 50 additional gallons of acid to the system on each such occasion. The system stability index jumped to as high as 9 before making a gradual drop back to the level of 3 or less. This cycle normally took a 3 to 4 day period for completion, as shown in the plot of stability factor for January, 1970, Figure 21.

The above practice was continued through August, 1970; stability factors through this period are shown on the first 4 monthly charts of Figure 22, on the following page. Eventually the corrosion of recycle system concrete sumps reached a critical state and continuous or frequent acid additions were halted. Starting in September, 1970, a different tack was taken; a chemical balance of the system was attempted by increasing the blow-down rate, which, up until now, had been held at a maximum of about 25%.

On Figure 22, the plot of stability indexes in September, 1970 shows the gradual climb of the index back to the 6.0 level, as the blow-down was increased to 50%.

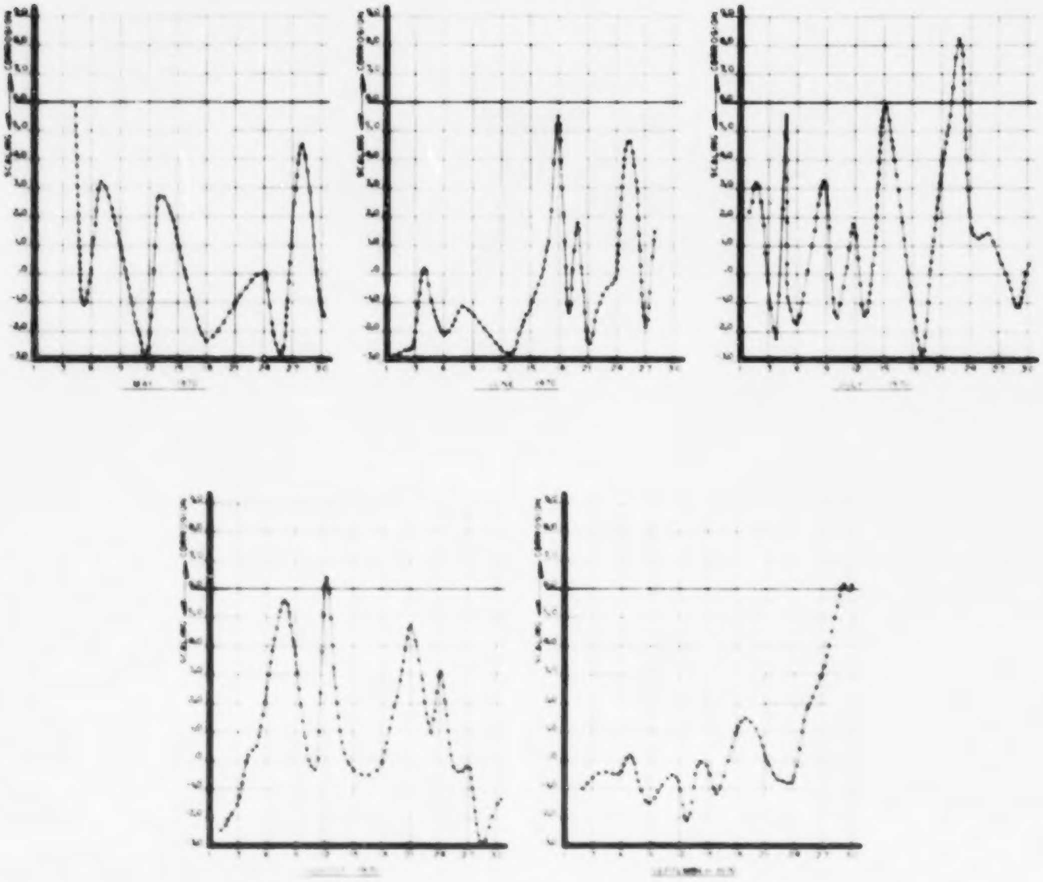

Fig. 22 Effect of Increase of Sinter Plant Water System Blow-down Rate from 25 Percent to 50 Percent

Figure 23 shows that the index remained at the higher level through the remainder of the plotted period.

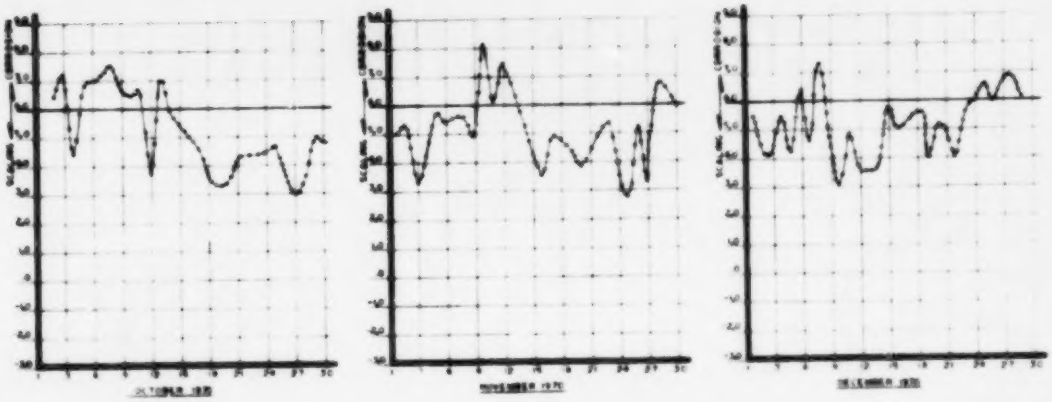

Fig. 23 Sinter Plant Water System Stability with 50 Percent Blow-down Rate

Starting in June, 1971, a new control concept was tried. The high blow-down rate was maintained, with no acid additions during the days of sinter plant operation (6 days a week). On shut-down day, acid was added, and pH was controlled in the 2 to 4 range, with a portable pH monitor. This practice, continued to this date, has been very effective in inhibiting scale formation in the sinter plant recycle system.

SECTION VII

ANALYSIS OF PERFORMANCE

The purpose of installing the recirculating water system at the blast furnaces and sinter plant was to eliminate the discharge of contaminated water to the Calumet River.

Prior to the installation of the recirculating system, the blast furnace and sinter plant wet scrubber water systems were shown in Figure 6 and described in Section IV. Table 7, shown on page 34 , shows typical analyses of the waters at different locations in the scrubber water system as they existed before recirculation. Also shown in Table 7 are the quality limitations of the Illinois Water Pollution Control Code (SWB-15), which had to be met. It should be noted that the Calumet River water does not meet this code in relation to content of suspended solids, hexane solubles, ammonia nitrogen, and cyanide. As stated on page 33 , the data in Table 7 generally represent the average values of a number of grab sample analyses. Not all analyses were performed on each sample, but it is believed that the tabulated figures are representative of the system water quality and quantity. See appendix E for complete tabulation of collected data.

Table 8 shows a material balance of the system. The figures in Table 8 were obtained by multiplying the concentrations shown in Table 7 by the corresponding flow figures, and applying the appropriate conversion factors for the units involved.

Control of Cyanides and Suspended Solids

It was intended that the recycle system would minimize the discharge of contaminants to the river, principally by reducing the levels of cyanide and suspended solids. Research had proven that the cyanide content could be effectively reduced by settling and aeration. Settling is also effective in reduction of suspended solids, particularly if it is preceded by proper flocculation.

TABLE 8

MATERIAL BALANCE PRIOR TO RECYCLE

Location	Flow (GPM)	Suspended Solids (#/Min.)	Hexane Solubles (#/Min.)	Ammonia Nitrogen (#/Min.)	Cyanide (#/Min.)	Phenol (#/Min.)	Iron (#/Min.)
Intake	24,400	10.5	3.7	1.0	.010	.0018	.67
North Sewer (CO-2)	11,300	7.6	1.7	.50	.038	.0044	.56
South Sewer (CO-3)	7,220	4.6	1.5	.084	.025	.0008	.15
Blast Furnace Clarifier Influent	3,690	28.6	.25	.49	.052	.0053	11.4
Blast Furnace Clarifier Effluent (CO-1)	3,490	1.3	.17	.29	.008	.0023	.33
Blast Furnace Clarifier Underflow	130	27.3	.08	.011	.044	.0030	11.1
*Sinter Plant Clarifier Influent	560	43.2	.06	.16	.037	.0019	12.9
Sinter Plant Clarifier Effluent Sinter Plant Outfall (CO-4)	630	1.6	.05	.14	.011	.0016	.18
Sinter Plant Clarifier Underflow	50	68.9	.09	.011	.070	.0033	23.8
Steam and Evaporation Loss	1,760	-	-	-	-	-	-
Total Discharge (Gross)		15.1	3.42	1.02	.082	.0091	1.22
Total Discharge (Net)		+ 4.6	- 0.28	+0.02	+ .072	+.0073	+ .55
Total Allowed (SWB-15)		4.72	2.8	.47	.006	.038	1.89

* Does not include underflow from Blast Furnace Clarifier

At both the blast furnace and sinter plant clarifiers, operators are presently feeding a cationic polymer, Nalco 610, in an amount of .05 parts per million, allowing it to mix, and are then introducing the anionic polyelectrolyte, Nalco 676, in an amount of one part per million. At each clarifier, a 600 gallon mixing tank with dispersant funnel and lightning mixer has been provided. This arrangement has been effective in flocculating fine particulates and thus increasing the thickener efficiency.

A reduction of cyanide level has been realized across both the blast furnace and sinter plant cooling towers. In section IV, page 43 , reference was made to tests conducted at coke plant cooling towers, and the results of these tests are tabulated in Appendix B. The coke plant cooling tower tests indicated an average cyanide removal of almost 50% by the aeration treatment, whereas data collected at the recycle system show that removal efficiency in such a system is only about 20 %. Checks have been made to determine if any free hydrogen cyanide gas is being liberated at the cooling tower, but no evidence of such gas has been found within the detectable limit of one part per million.

As described in other sections of this report, initial operation of the recycle system was accompanied by many difficulties. These difficulties were mainly associated with establishing a hydraulic balance. Once these problems were corrected and a good hydraulic balance was obtained, the system also achieved a reasonably good chemical balance.

Table 9 shows a typical chemical balance achieved once the system as diagrammatically shown on Figure 14 reached an acceptably stable operation. The data in Table 9 generally represent the average values of a number of grab sample analyses.

A tabulation of all collected data appears in Appendix E.

TABLE 9

RECYCLE SYSTEM - CHEMICAL BALANCE

Location	Flow (GPM)	Suspended Solids (ppm)	Hexane Solubles (ppm)	Ammonia Nitrogen (ppm)	Cyanide (ppm)	Phenol (ppb)	Iron (ppm)	pH
Intake	20,850	65	8.0	3.0	.014	13.6	1.9	8.1
North Sewer (CO-2)	11,300	46	8.0	2.3	.014	10.6	2.9	8.1
South Sewer (CO-3)	7,220	45	11.0	3.0	.019	6.4	2.0	8.2
Blast Furnace Clarifier Influent	4,500	1,038	7.5	64.	7.53	104	475	8.2
Blast Furnace Clarifier Effluent	4,300	41	4.0	64.	4.64	26	10	8.3
Blast Furnace Clarifier Underflow	130	34,600	125	60	107	2,800	16,150	8.5
*Sinter Plant Clarifier Influent	560	10,500	35.0	37	16.3	672	3,200	11.0
Sinter Plant Clarifier Effluent	630	400	14.0	31	9.40	18	37	11.0
Sinter Plant Clarifier Underflow	50	202,000	550	30	340	14,300	77,500	11.2
Steam and Evaporation Loss	1,740							
Blast Furnace System Blowdown	450	41	4.0	64	4.64	26	10	8.3
Sinter Plant System Blowdown	300	400	14.0	31	9.40	18	37	11.0
Sanitary Sewer Discharge	750	184	8.0	51	6.5	24	21	9.1
Sanitary Sewer Code	-	N/A	100	N/A	10.0	N/A	50	4.5 - 10
Code, SWB-15	-	25	15	2.5	.030	200	100	6 - 10

* Does not include underflow from Blast Furnace Clarifier.

Table 9 shows that the quality of non-contact effluents flowing to the river from the north and south sewers now essentially equals the intake river water quality.

Note that the river water analysis (with the exception of suspended solids content) now essentially meets the code, SWB-15, showing a general improvement in quality as compared with analyses taken prior to recycle, as recorded in Table 7. This fact has several possible explanations including the following:

1. Normal variation of water quality.

2. General river quality improvement in the 2 or 3 year interval.

3. Elimination of back-flow or cross-flow from Interlake outfalls to the intake. The Calumet River, at this point, usually exhibits no definite directional flow.

As previously stated, the process water blow-down from both the blast furnace system and the sinter plant system goes to the sanitary sewer. Although the sinter plant blow-down does not quite meet the sanitary sewer code, the composite discharge is well within code limitations.

Table 10 shows the mass balance of the recycle system. Figures in Table 10 were obtained by multiplying the concentrations shown in Table 9 by the corresponding flow figures, and applying the appropriate conversion factors. It should be noted that the combined cyanide mass rate from the north and south sewers is the same as the intake water. This indicates the successful separation of contact and non-contact waters in the blast furnace plant system.

Table 11, comprising selected data from Tables 7 and 9, is presented to provide a comparison of operation of the blast furnace system under once-through conditions as compared with recirculating conditions. The data clearly shows the effectiveness of the blast furnace clarifier in reducing suspended solids, cyanide and phenol. It is observed that the influent water quality on recycle is

TABLE 10

RECYCLE SYSTEM - MASS BALANCE

Location	Flow (GPM)	Suspended Solids (#/Min.)	Hexane Solubles (#/Min.)	Ammonia Nitrogen (#/Min.)	Cyanide (#/Min.)	Phenol (#/Min.)	Iron (#/Min.)
Intake	20,850	11.3	1.4	.52	.002	.0024	.33
North Sewer (CO-2)	11,300	4.3	.75	.22	.001	.0010	.27
South Sewer (CO-3)	7,220	2.7	.66	.18	.001	.0004	.12
Blast Furnace Clarifier Influent	4,500	39.0	.28	2.4	.283	.0039	17.8
Blast Furnace Clarifier Effluent (CO-1)	4,300	1.47	.14	2.3	.167	.0009	.36
Blast Furnace Clarifier Underflow	130	37.5	.14	.07	.116	.003	17.5
*Sinter Plant Clarifier Influent	560	49.1	.16	.17	.076	.0031	15.0
Sinter Plant Clarifier) Effluent)	630	2.10	.07	.16	.050	.0001	.19
Sinter Plant Clarifier Underflow	50	84.5	.23	.01	.142	.0060	32.3
Steam and Evaporation Loss	1,890						
Blast Furnace System Blowdown	450	.15	.01	.24	.017	.00010	.04
Sinter Plant System Blowdown	300	1.00	.04	.08	.024	.00005	.09
Sanitary Sewer Discharge	750	1.15	.05	.32	.041	.00015	.13

* Does not include Underflow from Blast Furnace Clarifier.

TABLE 11

WATER QUALITY CHANGES IN BLAST FURNACE SCRUBBER WATER SYSTEM

Blast Furnace Scrubber		Flow (GPM)	Suspended Solids (ppm)	Hexane Solubles (ppm)	Ammonia Nitrogen (ppm)	Cyanide (ppm)	Phenol (ppb)	pH
Once Through	- Clarifier Influent	3,690	928	8.0	16.0	1.70	171	8.4
	Clarifier Effluent	3,490	44.6	6.0	10.0	0.26	80	8.4
	Percent Removal		95%			85%	53%	
Recycle	- Clarifier Influent	4,500	1,038	7.5	64.	7.53	104	8.2
	Clarifier Effluent	4,300	41	4.0	64.	4.64	26	8.3
	Percent Removal		96%			38%	75%	

higher in content of ammonia nitrogen and cyanide.

The efficiency of the clarifier in removing cyanide is not as high on recycle as it is during once-through operation. The reason for this has not been determined, but it is possible that the cyanide is present in different forms depending on the nature of the operating mode. The mechanism of phenol removal is not clear; perhaps phenol is absorbed in the solids and removed when those solids are settled out.

Table 12 combines data available in Tables 8 and 10, in order to show the reduction (under recycle conditions) in the mass discharge of pollutants from the plant entity to the outside. This is one measure of the effect of the recycle system on the environment. The difference between line 1 and line 2a is the change in load to the Calumet River. The difference between line 1 and line 2A plus 2B is the change in load to the environment. Note that none of the tabulated figures is corrected for the quality of the river water intake.

Control of System Water Temperature

As discussed in some detail in Section IV, the decision to utilize cooling towers in both the blast furnace and sinter plant recycle systems was based on measured operating data, as well as certain assumed conditions and operating modes.

Actual temperature conditions in the systems have varied considerably from those assumed preliminary to design of the systems. Measured temperatures are shown in Table 13 (year-round averages):

TABLE 12

MASS DISCHARGE OF POLLUTANTS FROM CHICAGO PLANT

	Suspended Solids (lb./min.)	Hexane Solubles (lb./min.)	Ammonia Nitrogen (lb./min.)	Cyanide (lb./min.)	Phenol (lb./min.)
1. Once-Through System - Discharges to Calumet River (CO-1, 2, 3, 4)	15.1	3.42	1.02	.082	.0091
2. Recycle System					
A. Discharges to Calumet River (CO-2, 3)	7.0	1.41	.40	.002	.0014
B. Blowdowns to Sanitary Sewer	1.15	.05	.32	.041	.00015
C. Total All Discharges	8.15	1.46	.72	.043	.00155
Percent Reduction (1 to 2)	46%	57%	29%	48%	83%

TABLE 13

RECYCLE SYSTEM WATER TEMPERATURES

Blast Furnace System	
Clarifier Influent Temperature	- 140 degree F.
Clarifier Effluent Temperature	- 110 degree F.
Recycle Water Temperature	- 100 degree F.
River Water Temperature	- 50 degree F.
Sinter Plant System	
Clarifier Influent Temperature	- 92 degree F.
Clarifier Effluent Temperature	- 87 degree F.
Recycle Water Temperature (cooling tower not used)	- 87 degree F.

The implications of these data are as follows:

> The target temperature of 100 degree F. has been achieved in the blast furnace system cold well. The cooling tower is required in order to reach this temperature.
>
> The sinter plant system, as presently operated, does not require the cooling tower. When the system was designed, a blow-down rate much lower than the present 50% rate was assumed. With the present rate of blow-down, the water cooling requirements are drastically reduced. The high blow-down is required for chemical balance of the sinter plant system, and it is doubted that it will be possible to substantially change the water distribution without automatic control of chemical stability in the system.

Cost Analysis

The cost of engineering and building the combined blast furnace and sinter plant recirculating system was $1,109,400. A breakdown of the cost is presented in Table 14.

Operating costs of the system are tabulated in Table 15. The estimated additional cost of operating the recirculating system is shown to be about $23,700 per month, or $285,000 per year. Against this additional operating cost, there are potential savings which should accrue from a reduction of payments to the Corps of Engineers and from increased recovery of iron units formerly discharged to the river.

In accordance with a 1963 agreement with the Corps of Engineers, Republic Steel and Wisconsin Steel, Interlake has been paying (through 1971) $8,333 per year to the Corps, to remunerate them for solids discharged to the Calumet River and dredged from the river by the Corps of Engineers. Now that we have a negative net discharge to the river, we should be allowed to stop these payments. In addition to this saving, the value of the iron units in the solids formerly discharged amounts to about $1,700 per year.

Assuming the above two credits, the net additional cost of operating the recirculating system is about $275,000 per year.

Table 14

COST OF RECIRCULATING SYSTEM

Land		$ - 0 -
Buildings and Equipment:		
New 30' Diameter Sludge Concentrator at Sinter Plant	$ 68,900	
Sludge Pumphouse Extension at Sinter Plant	15,900	
Recycle Pumphouse at Sinter Plant	61,800	
Cooling Tower at Sinter Plant	51,500	
Piping at Sinter Plant	68,800	
Recycle Pumphouse at Furnace Plant	118,100	
Cooling Tower at Furnace Plant	138,500	
Coagulant Aid System at Furnace Plant	10,800	
Piping at Furnace Plant	261,000	
Interconnecting Sludge Piping	21,000	
Vacuum Pumps for Sludge Filters	23,100	
New Electric Power Supply, Including #4 Substation	86,200	
pH Control at Sinter Plant	16,600	
Spares	11,100	
		953,300
Revisions to Existing Equipment:		
Relocation of Existing Gas Cleaning Water Piping at Furnace Plant	$ 16,300	
Stove Water Diversion	22,800	
		39,100
Engineering:		
Engineering and Construction Supervision		117,000
Total Cost of Project		$1,109,400

TABLE 15

OPERATING COST OF RECIRCULATION SYSTEM

Direct and Indirect Labor	$ 13,100
Overtime and Other Premiums	900
Purchased Repair and Maintenance	3,500
Acids	900
Miscellaneous Operating Supplies (including Chemicals)	2,000
Repair and Maintenance Expense Distributed	6,300
Utilities Distributed	10,700
Labor Pool - Furnace Plant	200
Supervisory and Administrative Expense	11,700
Fixed Costs	4,400
* Monthly Operating Cost	$ 53,700

* The above cost is not the cost over and above the cost of supplying water to the original scrubber systems, and operating the clarifiers, filters, and other portions of the sludge handling system which existed prior to installation of the recirculating system.

The cost of operating the original scrubber water and sludge handling systems is estimated to have been about $30,000 per month.

SECTION VIII

ACKNOWLEDGMENTS

The valuable assistance of Dr. W. R. Samples and Dr. F. C. McMichael, senior fellows of the Mellon Institute Water Resources Fellowship, is gratefully acknowledged. The assistance rendered by Mellon Institute was supported by a research grant from the American Iron and Steel Institute.

The original studies of the Chicago Blast Furnace Plant water system and the design of the recirculating system were performed by Stanley Consultants of Muscatine, Iowa. This work was done under the leadership of Lowell D. Titus, L. G. Koehrsen and R. W. Richards.

The initiation of this project was accomplished by the Interlake, Inc. Environmental Control Project Team, consisting of F. K. Armour, Vice President-Engineering; W. P. Porcelli, Assistant Secretary and Corporate Attorney; H. H. Henderson, Director - Public Relations; and F. G. Krikau, Manager-Environmental Control. Refinement of design, field construction and initial system operation were carried out under the guidance of Interlake, Inc. Corporate Engineering Department personnel including R. S. Patton, R. P. Winters, T. R. Kinney, E. W. Lollock, R. F. Draus, and R. B. Bayr. This report was assembled and prepared by R. E. Touzalin.

The support of the project by the Environmental Protection Agency, and the assistance provided by Mr. Stephen Poloncsik, Research and Monitoring Program Representative and Mr. Clifford Risley, Jr., Project Officer, is acknowledged with gratitude.

SECTION IX

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SECTION XI

APPENDICES

APPENDIX A

PROCESSES FOR EFFLUENT TREATMENT

The processes considered for treatment of the various outfall contaminants included the following:

Cyanide

For the removal of cyanide three basic procedures were investigated.

1. Oxidation of Cyanide to Cyanate

Essentially this procedure involves raising the alkalinity of the effluent and treating it with an oxidizing agent. Typical of such processes is the method of "Alkaline Chlorination" which brings about the reaction:

$$NaCN + Cl_2 + H_2O \rightarrow NaCNO + 2HCl$$

Other oxidizing agents may be used, such as hypochlorite, chlorine dioxide, ozone, lime sulphur, silver nitrate, potassium permanganate or ferrous sulfate, but the basic mechanism of reaction remains the same.

2. Acidification

If water containing a cyanide is acidified to a pH below 6, the cyanide is converted to hydrogen cyanide gas which evolves from the water. The reaction is as follows:

$$NaCN + HCl \rightarrow NaCl + HCN\uparrow$$

This process is impractical due to the toxicity of the hydrogen cyanide gas.

3. Biological Degradation by Activated Sludge

   After careful preconditioning, activated sludge is capable of effecting a significant reduction in the cyanide content of an effluent.

Phenol

For the removal of phenol, three methods were considered.

4. Absorption

   Phenols and analogous compounds can be removed by the use of a liquid-liquid extraction tower using either light oil or benzol. The phenol is recovered from the light oil by absorption in a caustic soda solution, to form sodium phenolate.

5. Extraction

   Multi-stage centrifugal extractors of the Podbielniak type will remove phenol from a liquid effluent.

6. Biological Degradation by Activated Sludge

   As is the case with cyanide, phenols may be degradated by biological activity.

Suspended Solids

Practical experience with this category of pollutants provided a basis for evaluation of the two most effective treatment methods:

7. Secondary Clarification

   This involves the settling out of fine particulates in a secondary clarifier which would handle the effluent from existing clarifier units. The secondary unit would provide a longer dwell time and lower rise rate than that of the existing units.

8. Flocculation

Chemical flocculation could be performed in the existing clarifiers, or could be used in conjunction with secondary clarification. Aggregation of fine particulates into large flocs would increase the settling rate of suspended solids and substantially reduce the concentration of suspended solids in effluent waters.

Others

Other commonly accepted methods which were reviewed relative to treatment of plant effluents were acid addition for pH control and evaporative cooling for temperature control.

APPENDIX B

CYANIDE TREATMENT IN A COOLING TOWER

As part of an investigation of odor control in Marley cooling towers, Interlake's Corporate Research Department conducted extensive water testing at the Chicago and Toledo Coke Plants during March, April, May, and July, 1971. The data resulting from this study is tabulated on Table 16. Although the waters being analyzed varied in quality from that in a blast furnace recycle system, the effectiveness of aeration in reduction of cyanide concentration is further demonstrated by this data.

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TABLE 16 Analyses of the Waters from the Marley Cooling Towers at the Toledo and Chicago Coke Plants

		Concentrations, mg/l (except pH)									
	Date of	Before Marley Tower(1)					After Marley Tower				
Plant	Sample	NH_3	CN^-	$S^=$	$SO_4^=$	pH	NH_3	CN^-	$S^=$	$SO_4^=$	pH
Toledo	c. March 25	3750	354	743	135	8.9	3525	255	606	130	8.9
	May 18	3125	425	534	-	9.2	2710	145	42	-	9.2
	May 19	2890	310	463	-	9.2	2430	113	101	-	9.1
Chicago	April 4	1000	275	7	902	8.3	963	170	7	887	8.4
	April 30	850	258	-	110	8.3	750	175	-	10	8.3
	May 3	650	308	17	120	8.1	550	193	-	170	8.2
	May 4(2)	2100	370	810	50	9.2	1150	178	63	75	9.2
	May 5	675	245	1.4	150	8.5	600	133	11	135	8.5
	May 6	675	260	-	190	8.5	625	170	-	165	8.4
	May 18	850	349	63	-	7.9	750	180	14	-	7.9
	May 19	1450	450	44	-	8.0	1100	210	15	-	8.1
	July 22	1060	-	-	-	-	860	-	-	-	-

(1) Before Marley Tower refers to water flowing from the final coolers to the top of the Marley tower. After Marley Tower refers to water flowing from the bottom of the Marley tower to the final coolers.

(2) On May 4, the ammonia absorber at the Chicago Plant was by-passed because of operating problems. Make-up water was added to the system at a high rate.

APPENDIX C

SCALE FORMATION AND CONTROL (STABILITY INDEX)

In its travel through a gas-contact system, water may become associated with and dissolve a variety of chemicals. Some of these chemicals will induce a corrosive condition, while others will propagate the formation of scale. People concerned with boiler feed systems are very much aware of this problem and have been studying and attempting to control it for many years.

Generally, the term "scale" applies to deposits which result from crystallization or precipitation of salts from solution. However, the corrosion or eating away of a metal may also result in a deposit (iron oxide). In each case, the mechanism of formation is different and must be treated in a different way.

In blast furnace gas scrubber water systems, the formation of carbonate scale is normally prevalent. Calcium carbonate is usually the chief ingredient of scale formation due to its low solubility in water, which solubility decreases as the temperature increases. The factors that affect scale formation are temperature, calcium, magnesium, silica, alkalinity, dissolved solids, and the pH of the water.

Two useful tools that are generally used to predict the scaling tendency, in a water system, are the Langlier's Saturation Index and the Ryznar Stability Index. These indexes, which take into consideration the quantitive values of pH, calcium, total alkalinity, dissolved solids, and temperature, are applicable for waters with a pH between 6.5 and 9.5.

The equations for both of these indexes take into account the pH at which water is in equilibrium with calcium carbonate (pHs). In a laboratory test, equilibrium is assumed to be reached after standing overnight in contact with pure $CaCO_3$. The pH value measured is the pHs. pHs can also be determined from the parameters noted above by the relationship:

$$pHs = 6.301 + pK_2 - pK_s + pCa + pA + S + F_t \quad (1)$$

Where:

p	the negative logarithm (base 10)
K_s	the second dissociation constant for carbonic acid in water; this equals 4.83×10^{-9}
K_2	the activity product of calcium carbonate in water; it equals 4.69×10^{-11}
Ca	the calcium ion concentration in milliequivalents/liter (me/l)
A	total alkalinity as calcium carbonate (me/l)
S	a function of the ionic strength u; this is known as the Larson and Buswell Salinity Correction Factor, having the relationship shown in Formula 3 of the sample calculation (page 102).
F_t	the temperature correction factor; see Formula 4 in sample calculation.

The effects of temperature on pHs are shown on Figure 48. Note that the saturation pH (pHs) increases with increases in temperature.

Langliers' Saturation Index is defined as the algebraic difference between the actual measured pH of the water and the calculated pHs at saturation with calcium carbonate.

$$I_L = pH - pHs$$

This index shows qualitatively the tendency for deposition or solution of calcium carbonate. A positive index indicates scaling tendencies, and a negative index indicates corrosive trends. A zero index denotes that the system is in equilibrium with calcium carbonate. While a high

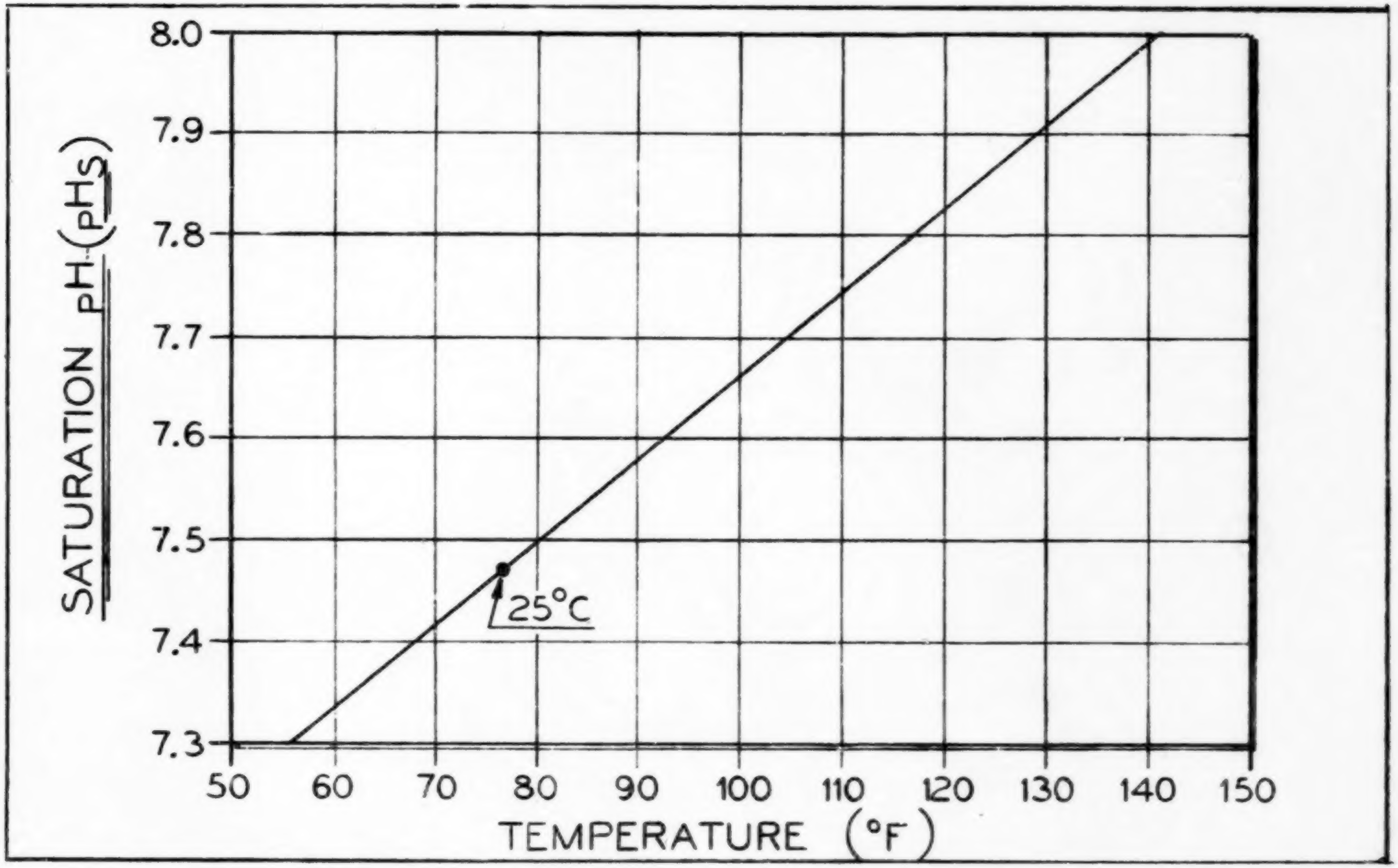

Fig. 48 - Temperature Effects on Saturation pH (pHs)

hardness water, with a positive Saturation Index will definitely lead to calcium carbonate scale formation, a low hardness water with the same positive Saturation Index may not form any appreciable amount of scale.

In an attempt to secure a quantitative index, Ryznar proposed the Stability Index:

$$I_R = 2\ \mathrm{pHs} - \mathrm{pH}$$

When the Index is higher than 7.5 to 8, a corrosive condition exists. At levels above 6 to 7, scale will tend not to form. If the water has an Index lower than 6, the tendency is to form scale and lessen the possibility of corrosion.

Although neither index is completely reliable, they give an operator a useful tool by means of which he may monitor his system. For this reason we use the Ryznar Stability Index as a control mechanism.

Sample calculations of indexes follow:

Sample Calculation

With a given water, having the following analysis, calculate the Ryznar and Langlier indexes.

pH	8.1
Temperature	102 F (38.9 C)
$CaCO_3$	28 mg/l
$MgCO_3$	175 mg/l
Alkalinity	375 mg/l
Conductivity	1900 umho/cm^3

Ionic Strength (u)

u, the ionic strength, is a function of the summation of the product of all dissolved chemical concentrations (c_i) and their charge (z_i). It is formulated as follows:

$$u = 5 \times 10^{-4} \times c_i z_i \qquad (2)$$

All of the chemicals dissolved in water contribute to the total ionic strength of a solution. For simplicity of calculation, only the major contributors, Magnesium and Calcium Carbonates, will be considered.

The milliequivalent weight of the calcium (Ca) ion in Calcium Carbonate is 20.08; for Magnesium (Mg), it is 12.2. The charges associated with Ca and Mg are plus 2. The calculation proceeds as follows:

$$u = 5 \times 10^{-4} \times (c_1 z_1 + c_2 z_2)$$

$$u = .0005 \times \left(\frac{28}{20.04} \times 2 + \frac{175}{12.2} \times 2\right) = .0157$$

Salinity Correction Factor (S)

$$S = \frac{2.5\ u}{1 + 5.3\ u + 5.5\ u} \qquad (3)$$

$$S = \frac{2.5\ (.0157)}{1 + 5.3\ (.0157) + 5.5\ (.0157)} = .179$$

Temperature Correction Factor (F_t)

$$F_t = (T-25)\ .015 \qquad (4)$$

$$F_t = (38.9-25)\ .015 = .21$$

Saturation pH (pHs)

$$pHs = 8.313 + pCa + pA + S + F_t \quad (1)$$

$$pHs = 8.313 + - \log 10 \left(\frac{28}{20.04}\right) + \log 10 \left(\frac{375}{50}\right)$$

$$+ .179 + .21$$

$$= 8.702 - \log_{10} (1.387) - \log_{10} (7.5)$$

$$= 8.702 - .143 - .875 = 7.684 \text{ or } 7.7$$

Ryznar Stability Index

$$I_R = 2\ pHs - pH = 2\ (7.7) - 8.1 = 7.3$$

Langlier Saturation Index

$$I_L = pH - pHs - 8.1 - 7.7 = .4$$

During operation of the recycle system the Nalco Aquagraph was used to determine the stability of the systems. This device, which applies the slide rule principle to a nomograph-type determination, used the relationship between conductivity and dissolved solids, in addition to the factors used in the sample calculations.

$$\text{Conductivity} = 1900 \text{ umho/cm}^3$$

$$\text{Dissolved Solids} = 1900/1.9 = 1000 \text{ mg/l}$$

The above value, 1.9, was determined during the operation of the recycle system; data was obtained and the correlation between conductivity and dissolved solids was found to be 1.9 ± .2 for our system.

$$\frac{\text{Conductivity}}{\text{Dissolved Solids}} = 1.9 \pm .2$$

For a demonstration of the use of the Nalco Aquagraph, refer to Figure 49.

Procedure:

1. Select the water temperature, 102°F, on scale "A", and move scale "B" so that the P.P.M. (parts per million) of dissolved solids, 1000, is opposite 102° F.

2. Scale "C" is integral with, and moves with, scale "B".

3. Move scale "D" so that the P.P.M. total alkalinity, 375, is opposite the P.P.M. of Calcium ($CaCO_3$) 28, on scale "C".

4. On scale "E", locate the system pH, 8.1. Read the Stability Index on scale "F" opposite 8.1 on scale "E". The indicated Stability Index is 7.1.

APPENDIX D

NOTES ON RECYCLE OBJECTIVES AND PROCEDURES FOR A COMBINED BLAST FURNACE AND SINTER PLANT GAS CLEANING SYSTEM FOR INTERLAKE STEEL CORPORATION

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2 JUNE 1969

This work was supported by a research grant from the American Iron and Steel Institute.

The purpose of this report is to summarize some of the ideas and questions resulting from a visit by W. R. Samples and F. C. McMichael of the Water Resources Fellowship with R. E. Touzalin, F. G. Krikau, E. Lollock, R. Bayr, and R. Patton of Interlake Steel Corporation on 24 April 1969 in Chicago. Interlake is undertaking a research and development grant from the Federal Water Pollution Control Administration for pollution control of a blast furnace gas washer through recirculation. The Fellowship has been carrying on research on water quality changes resulting from the recycle of gas cleaning waters for the past three years and welcomed this opportunity to participate in a controlled full-scale study.

The numbered statements in this report are made directly to the participants at the Chicago meeting. By themselves they may appear sparse, but hopefully they contain the kernel of that meeting.

1. To observe and control the operation of a recycle water system, it is necessary to make a total water and material balance which encompasses the whole system. This means that all make-up water inputs and all discharge points must be monitored for volume of flow as well as the chemical and physical description of the water. Economically and operationally this suggests that the make-up locations and the discharge (or blowdown) locations be kept to an absolute minimum. The ideal system for monitoring should have only one make-up water location and one blowdown location. Simply, operation requires a description of the quantity and quality of water throughout the system.

2. The chemical and physical parameters of the water system can be classed advantageously as conservative and non-conservative. Conservative substances, such as sodium and chloride, are added to the water by the gas cleaning process and generally tend to build up in concentration with time. By the means of blowing down, or discharging from the system, a portion of the gas cleaning water, the concentration of the conservative substances can be held nearly constant. Non-conservative substances, on the other hand, are also added to the water by the gas cleaning process. These substances may undergo chemical reaction and be precipitated, be volatilized, or otherwise be lost from the system. Their behavior is not readily predicted. The system of calcium, alkalinity, pH, ionic strength, and temperature is a group of interacting or non-conservative substances. These non-conservative materials are also effected by blow-down. It is necessary for operational control to determine the response of the water recycle system with regard to the non-conservative substances. Broadly, some non-conservative substances may change concentration by large amounts, reach saturation levels, precipitate, and entirely change the chemical composition of the recycle water stream. The prediction and control of this chemical system is the principal problem of the recycle operation. Ideally, this system should be controlled with a minimum of outside activity. Hopefully, control of the non-conservative

substances may be managed by the same technique as for the conservative substances, that is, blow-down from the system.

3. To predict recycle system performance and measure system response, the following parameters must be measured at all input (make-up) and discharge (blow-down) locations of the recycle water system with the frequency noted. Regular intervals at this time cannot be well defined.

   Physical

   1. Flow-continuous monitoring.
   2. Temperature-regular intervals or continuously.
   3. Suspended Solids-regular intervals.

   Chemical - for operation control.

   1. Calcium.
   2. Magnesium.
   3. Alkalinity.
   4. pH.
   5. Conductivity (dissolved solids) - continuous monitoring.

   Chemical - for pollution control (blowdown).

   1. Ammonia.
   2. Cyanide.
   3. Phenolics.
   4. Iron.

   Chemical - for further system analysis and control.

   1. Sodium - less frequent intervals.
   2. Chloride - less frequent intervals.
   3. Total inorganic analysis - cation and anion balance - composite samples over a complete operational interval.

4. Interlake Sampling Locations

All additions and subtractions from the water system must be accounted for by measurement. Locations refer to flow schematic CA-3253, Interlake Steel Corporation.

Blast Furnace System

1. Influent to 90 ft. diameter clarifier, say at gas washer pump house.
2. Pump discharge from manifold leading to blast furnace cooling tower.
3. Effluent line from blast furnace cooling tower.
4. Blowdown (6 in. diameter) line from manifold leading to blast furnace cooling tower (flow rate only).
5. Make-up water (6 in. diameter) line leading to pump sump for blast furnace cooling tower pumps.
6. Discharge manifold from sludge pumps leading to 4 in. diameter sludge line to sinter plant system.
7. Blowdown from new 4 in. diameter sludge line and old 4 in. diameter sludge line.
8. Presently there are three additional discharge points, two from the stoves, and one overflow before the gas washer pump house, that must be eliminated from system or monitored when used.

Sinter Plant System

1. Mill water line which provides make-up water.
2. Inlet trough to 40 ft. diameter clarifier.

3. Outlet from 40 ft. diameter clarifier leading to pump sump for sinter plant cooling tower.

4. Effluent line from sinter plant cooling tower.

5. Blowdown (4 in. diameter) line from manifold from sinter plant recycle pumps (flow rate only).

6. Blowdown line (trench) from 40 ft. diameter clarifier leading to outfall CO-4.

5. Frequency of Sampling

Flow rate at input and discharge points should be monitored continuously. Other physical and chemical parameters may be measured at selected intervals. The frequency of sampling is based on the response time of the gas washer water system. One measure of this response time is the detention time obtained by dividing the volumetric capacity of the water system by the flow rate through the system.

Blast Furnace	Volume
1. Clarifier - 90 ft. diam., 12 ft. deep.	76,000 ft.^{3}
2. Cooling tower reservoir - 2 ft. x 22-1/2 ft. x 62-1/2 ft.	2,800
3. Cooling tower pump sump - 20 ft. x 15 ft. x 9 ft.	2,700
4. Recycle pump sump - 20 ft. x 15 ft. x 9 ft.	2,700
Total	84,200 ft.^{3}

$$\text{Estimated detention time} = \frac{84{,}200 \text{ ft.}^3}{4{,}200 \text{ gpm}} \times \frac{7.48 \text{ gal.}}{\text{ft.}^3} = 150 \text{ minutes} = 2\text{-}1/2 \text{ hours}$$

Sinter Plant	Volume
1. Clarifier - 40 ft. diam., 17 ft. deep.	21,400 ft.^{3}
2. Cooling tower pump sump - 12-1/2 ft. x 10 ft. x 10 ft.	1,250
3. Recycle pump sump - 12 1/2 ft. x 10 ft. x 10 ft.	1,250
Total	23,900 ft.^{3}

$$\text{Estimated detention time} = \frac{23{,}900 \text{ ft.}^3}{600 \text{ gpm}} \times 7.48 \frac{\text{gal.}}{\text{ft.}^3} = 300 \text{ minutes} = 5 \text{ hours}$$

The chemical parameters sampled most frequently should not be monitored at intervals more often than say one-half the detention time. Sampling at intervals shorter than one detention time should be done only when the system is undergoing change. Less frequent sampling is required when the system is nearly at steady state. Changes in operation should not be made more frequently than several detention times. If the system were completely mixed, it would take about three detention times to flush out 95 percent of a conservative contaminant.

6. Presently the plan of operation for the combination of the blast furnace and sinter plant gas washer systems is to use the blowdown from the blast furnace system to provide the make-up water for the sinter plant system. The blowdown from the blast furnace system carries the solids from the blast furnace clarifier to the sinter plant system, that is, to the sinter plant thickener. This technique of maintaining a relatively dilute underflow for solids removal and blowdown seems to be a good idea. Steel industry experience to date shows that a blast furnace gas washer system can be operated on recycle using blowdown as the operational control at 20 percent blowdown. Tighter recycle with less blowdown than 20 percent requires more operational

care than presently has to be provided with once-through operation. Using the 20 percent blowdown value as a starting point, and a volume flow rate of 4200 gpm for the blast furnace system, results in a blowdown of 840 gpm being delivered to the sinter plant system. The present flow rate of the sinter plant gas washer system is about 600 gpm which means that at 20 percent blowdown from the blast furnace system water is being supplied to the sinter plant cleaning operation at a rate that requires 100 percent blowdown or once-through cleaning. If the blast furnace system is tightened to 5 percent blowdown, or say 210 gpm makeup to the sinter plant system, the sinter operation can be put on recycle of about 67 percent. These flow rates are based on water discharge only excluding evaporation losses and moisture losses with filter cake removal. The question that presents itself is the magnitude of the ultimate blowdown from the combined operations - its location, quantity and quality. To recycle water in the sinter plant operation will require some type of alkalinity control which in steady operation means the removal per cycle of the incremental addition of alkalinity added to the gas cleaning water. There are alternative ways of controlling alkalinity. More than likely precipitated calcium carbonate can be removed in the clarifier and acid can be added for pH control. Disposal and treatment of the ultimate blowdown will depend wholly on the tightness of the recycle.

7. Two direct statements of Fellowship experience with blast furnace recycle systems should be made regarding pollution abatement. Our analyses show that the quality of clarifier effluents from once-through and recycle operations in terms of suspended solids remains about the same. This means that for the blast furnace system, by itself, the percent reduction in volumetric discharge by the recycle operation represents the percent reduction in solids disposed of to the receiving water course. Cyanide concentrations in recycle waters similarly do not seem to show large increases in concentration and consequently the recycle operation can appreciably affect the total mass discharge of these two particular pollution parameters.

APPENDIX E

DATA TABULATION

DATA KEY

TIME: BASED ON A 2400 HOUR CLOCK

LOCATION:

1. TROUGH TO PRIMARY CLARIFIER
2. OVERFLOW FROM PRIMARY CLARIFIER
3. SUMP TO COOLING TOWER-PRIMARY
4. SUMP RECYCLE WATER-PRIMARY
5. RIVER WATER-MAKE UP
6. BLOWDOWN FROM BLAST FURNACE SYSTEM
7. SLUDGE FROM PRIMARY TO SINTER PLANT CLARIFIER
8. SCRUBBER WATER TO SECONDARY THICKENER
9. OVERFLOW FROM SECONDARY THICKENER
10. SUMP TO COOLING TOWER-SECONDARY
11. SUMP FROM COOLING TOWER-RECYCLE WATER
12. SLUDGE FROM SECONDARY THICKENER
13. BLOWDOWN-SECONDARY
14. OVERFLOW SLUDGE TANK

CONDUCTIVITY: UMHOS/CM @ 25°C

CACO3: CALCIUM CARBONATE-MG/L

MGCO3: MAGNESIUM CARBONATE-MG/L

ALKALINITY: MG/L

SUSP. SOLIDS: FILTERABLE SOLIDS-MG/L

PH: PH OF STSTEM

PHS: SATURATION PH-CALCULATED

I: STABILITY INDEX
<6 PLATING SITUATION
>6 CORROSIVE SITUATION

IS: SATURATION INDEX
<0 CORROSIVE SITUATION
>0 PLATING SITUATION

°F: TEMPERATURE

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NO. OF OBSERVATIONS=          1167

   DATE    TIME  LOCATION  CONDUCTIVITY    CACO3     MGCO3   ALKALINITY   SUSP.SOLIDS   PH   PHS      I/IS

 11/10/69   400      1           1130     150.80    138.80       310        #########   7.8   6.8   5.9/ +1.0
 11/10/69   400      2           1140     146.90    132.10       105             52.3   7.9   7.3   6.7/ +0.6
 11/10/69   400      5            320     115.10     42.60        85             29.2   7.5   7.5   7.4/ +0.0
 11/10/69   400      6           1160     196.50    115.40       305             56.4   8.2   6.7   5.2/ +1.5
 11/10/69   400     10            990     174.90    114.50       260            212.0   8.1   6.8   5.6/ +1.3
 11/10/69  2100      1           1280     123.10    192.30       350            334.6   8.1   6.9   5.6/ +1.2
 11/10/69  2100      2           1180     135.30    199.80       305             41.6   8.0   6.9   5.8/ +1.1
 11/10/69  2100      5            300     109.20     46.00       170              4.4   7.5   7.2   6.9/ +0.3

 11/12/69  2300      1           1260      39.70    282.60   #########          480.6   8.4  ####  #####/#####
 11/12/69  2300      2           1272      54.60    293.40       490             78.4   8.4   7.1   5.8/ +1.3
 11/12/69  2300      4           1180      48.60    280.10       455             69.6   8.5   7.2   5.9/ +1.3
 11/12/69  2300      5            300      69.50     76.90       125             30.4   7.8   7.5   7.3/ +0.3
 11/12/69  2300      9           1216      65.50     55.20        51            101.6   9.9   7.9   6.0/ +2.0
 11/12/69  2300     14           1508      59.60    127.10       170             92.8   9.3   7.5   5.6/ +1.8

 11/13/69   500      1            720     216.40    205.30       380            553.2   8.0   6.6   5.2/ +1.4
 11/13/69   500      2           1200     113.10    212.30       348             93.2   8.2   6.9   5.6/ +1.3
 11/13/69   500      3           1140     105.20    205.70       350             97.6   8.4   6.9   5.5/ +1.5
 11/13/69   500      5            276     103.20     49.30        11             53.2   7.9   8.4   8.9/ -0.5
 11/13/69   500      9           1480     379.10     21.70        37             55.2  12.0   7.4   2.7/ +4.6
 11/13/69   500     14           1140     119.10    107.80       260            112.4   9.3   7.0   4.7/ +2.3
 11/13/69  1100      1           1560      96.20    177.20       610           4655.0   8.4   6.7   5.3/ +1.7
 11/13/69  1100      3           1340      83.40    152.10       475             93.2   8.2   6.9   5.6/ +1.3
 11/13/69  1100      4           1440      85.40    227.70       520             97.6   8.3   6.9   5.4/ +1.4
 11/13/69  1100      5            310     107.20     71.40       105             26.9   7.9   7.4   6.9/ +0.5
 11/13/69  1100      6           1400      66.30    198.90       505             87.6   8.3   6.8   5.3/ +1.5
 11/13/69  1701      9           1360     353.30     26.80       275             45.2  11.7   6.5   1.3/ +5.2
 11/13/69  1701     14            930   ########  ########        46            342.5  10.0  ####  #####/#####
 11/13/69  2001      9           5100     476.40   2257.20       500            110.9   6.1   6.2   6.3/ -0.1
 11/13/69  2001     14           1100      77.41    133.80        32             79.6   9.0   8.1   7.2/ +0.9
 11/13/69  2101      9           7600     790.10    206.50        75            184.0   6.1   6.8   7.5/ -0.7
 11/13/69  2101     14           1200     426.70    130.40       325             50.8   8.8   6.4   4.0/ +2.4
 11/13/69  2301      9           6400     637.20    180.60        75            288.4   6.9   6.9   6.8/ +0.0
 11/13/69  2301     14           1400     174.60    513.30       310             35.2   8.5   6.8   5.1/ +1.7

 11/14/69   100      4           4540   ########  ########  #########           132.8   8.9  ####  #####/#####
 11/14/69   100      9           4500   ########  ########        40             86.0   9.4  ####  #####/#####
 11/14/69   100     14           1400   ########  ########       315             16.8   8.4  ####  #####/#####
 11/14/69   300      4           4700   ########  ########  #########            58.8   9.6  ####  #####/#####
 11/14/69   300      9           4100   ########  ########        80            108.8   8.9  ####  #####/#####
 11/14/69   300     14           1430   ########  ########       335             34.8   8.4  ####  #####/#####
 11/14/69   500      1           1360      77.40    248.10       490           1580.0   8.2   6.9   5.7/ +1.3
 11/14/69   500      2           1360     143.90    196.10       490             95.0   8.2   6.7   5.1/ +1.5
 11/14/69   500      3           1120      74.40    208.50       405             99.2   8.3   7.0   5.7/ +1.3
 11/14/69   500      4           1360     152.80    172.20       470             95.6   8.3   6.6   5.0/ +1.7
 11/14/69   500      5            320     148.90    167.20       115             48.8   8.0   7.3   6.5/ +0.7
 11/14/69   500      6           1300     143.80    200.60       480             93.0   8.2   6.7   5.1/ +1.5
 11/14/69   500      8           4000    2004.90    693.90        75           1662.0   6.6   6.4   6.2/ +0.2
 11/14/69   500      9           5080    2347.30    773.30        60            196.3   6.7   6.4   6.1/ +0.3
47
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DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
11/14/69	500	10	4300	1935.40	827.60	90	146.4	6.9	6.3	6.0/ +0.6
11/14/69	500	12	4600	1930.40	714.80	165	3337.0	7.7	6.1	4.4/ +1.6
11/14/69	500	13	4475	1786.50	723.00	67	127.0	7.5	6.5	5.5/ +1.0
11/14/69	500	14	1480	129.00	203.90	335	45.6	8.3	6.9	5.4/ +1.4
11/14/69	600	4	6400	##########	##########	##########	128.0	7.2	#####	######/######
11/14/69	600	9	5660	##########	##########	##########	76.8	6.2	#####	######/######
11/14/69	600	14	1450	##########	##########	##########	59.2	8.4	#####	######/######
11/14/69	900	11	4000	##########	##########	##########	##########	7.7	#####	######/######
11/14/69	900	14	1680	##########	##########	##########	##########	8.5	#####	######/######
11/14/69	1100	1	1280	25.80	252.50	425	661.2	8.3	7.5	6.6/ +0.8
11/14/69	1100	2	1480	79.00	195.50	505	104.0	8.2	6.9	5.8/ +1.3
11/14/69	1100	3	1460	83.10	192.20	535	100.0	8.2	6.8	5.5/ +1.4
11/14/69	1100	5	320	110.20	91.10	110	27.2	7.9	7.4	6.6/ +0.5
11/14/69	1100	6	1480	45.70	245.70	530	96.4	8.2	7.1	6.0/ +1.1
11/14/69	1100	8	4600	1901.40	756.60	285	4100.0	8.5	5.9	3.2/ +2.6
11/14/69	1100	9	5060	2153.70	677.20	55	122.0	7.3	6.5	5.9/ +0.8
11/14/69	1100	10	4700	1341.10	736.40	90	100.0	7.3	6.3	5.6/ +1.0
11/14/69	1100	12	4600	1657.50	827.60	90	16020.0	7.8	6.4	5.0/ +1.4
11/14/69	1100	14	2010	357.30	334.40	60	45.6	8.8	7.2	5.8/ +1.5
11/14/69	1130	9	##########	##########	##########	##########	##########	9.8	#####	######/######
11/14/69	1130	14	##########	##########	##########	##########	##########	8.5	#####	######/######
11/14/69	1330	9	##########	##########	##########	##########	##########	10.0	#####	######/######
11/14/69	1330	11	5130	1663.00	423.00	73	143.5	7.9	6.5	5.1/ +1.4
11/14/69	1330	14	##########	##########	##########	##########	##########	8.6	#####	######/######
11/14/69	1700	1	2000	71.50	237.40	535	299.6	8.1	6.9	5.7/ +1.2
11/14/69	1700	3	1560	49.60	225.70	625	94.8	8.1	7.0	5.9/ +1.1
11/14/69	1700	5	320	108.20	66.00	110	25.6	7.9	7.4	6.9/ +0.5
11/14/69	1700	6	1520	79.40	170.50	90	87.6	8.2	7.6	7.1/ +0.6
11/14/69	1700	8	9800	3290.10	973.90	160	23072.0	6.1	5.8	5.6/ +0.3
11/14/69	1700	9	7200	2332.50	810.90	55	139.8	6.4	6.5	6.7/ -0.1
11/14/69	1700	10	6000	1915.50	443.10	60	155.2	6.6	6.5	6.4/ +0.1
11/14/69	1700	12	6000	2203.40	627.00	70	3283.6	6.7	6.4	6.1/ +0.3
11/14/69	1700	13	4600	1960.90	620.50	55	172.0	7.0	6.6	6.3/ +0.4
11/14/69	1700	14	2080	347.40	342.80	135	58.0	8.3	6.9	5.4/ +1.4
11/14/69	2300	1	1520	127.10	356.10	560	79.6	8.3	6.7	5.0/ +1.6
11/14/69	2300	3	1720	93.20	219.90	465	74.4	8.2	6.9	5.7/ +1.3
11/14/69	2300	5	460	100.20	68.60	100	37.6	7.7	7.5	7.2/ +0.2
11/14/69	2300	6	1720	39.70	229.90	470	77.6	8.1	7.2	6.5/ +0.9
11/14/69	2300	8	5000	1181.10	533.20	75	20843.0	9.4	6.6	4.0/ +2.8
11/14/69	2300	9	4700	1951.00	614.50	70	102.8	8.2	6.5	4.9/ +1.7
11/14/69	2300	10	4700	1840.10	594.20	70	133.2	8.2	6.6	4.9/ +1.6
11/14/69	2300	12	4300	1627.70	614.50	55	355.6	7.0	6.6	6.2/ +0.4
11/14/69	2300	13	4600	1498.70	551.80	65	147.2	8.2	6.6	5.0/ +1.6
11/14/69	2300	14	2600	530.90	422.20	65	85.6	8.7	7.0	5.3/ +1.7
11/14/69	2300	14	2500	76.40	298.50	340	84.0	8.2	7.1	6.0/ +1.1
11/14/69	2330	4	##########	##########	##########	##########	##########	8.5	#####	######/######
11/15/69	500	2	1160	182.60	110.40	340	96.4	8.0	6.7	5.4/ +1.3
11/15/69	500	3	1160	158.80	127.10	325	100.0	8.1	6.8	5.5/ +1.3
11/15/69	500	4	1200	69.50	220.70	350	89.6	8.4	7.1	5.8/ +1.3

146

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
11/15/69	500	5	380	107.20	56.00	105	51.6	7.8	7.4	7.0/ +0.4
11/15/69	500	9	6000	2501.10	798.40	135	108.8	8.8	6.0	3.3/ +2.8
11/15/69	500	11	5060	2014.80	714.00	100	141.6	6.8	6.3	5.7/ +0.5
11/15/69	500	13	5000	2004.90	695.00	105	159.6	6.5	6.2	6.0/ +0.3
11/15/69	500	14	2840	152.80	920.40	120	84.8	7.2	7.3	7.4/ -0.1
11/15/69	1100	1	1260	214.40	80.30	375	369.6	7.9	6.6	5.5/ +1.3
11/15/69	1100	2	1240	23.80	236.50	360	59.2	7.9	7.6	7.5/ +0.3
11/15/69	1100	3	1220	31.80	219.00	370	54.0	8.0	7.4	7.1/ +0.6
11/15/69	1100	4	1240	27.80	211.50	365	48.0	8.1	7.5	7.1/ +0.6
11/15/69	1100	5	340	46.60	157.80	105	72.0	7.9	7.8	7.4/ +0.1
11/15/69	1100	6	1240	25.80	224.90	365	52.0	8.1	7.5	6.9/ +0.6
11/15/69	1100	9	4600	1692.20	622.80	45	136.4	7.9	6.7	5.5/ +1.2
11/15/69	1100	13	4300	1543.30	570.20	55	78.0	8.0	6.6	5.3/ +1.4
11/15/69	1700	1	1540	23.80	192.20	560	518.8	7.0	7.4	7.9/ -0.4
11/15/69	1700	3	1380	15.90	209.80	445	186.4	8.0	7.6	7.6/ +0.4
11/15/69	1700	6	1400	31.80	172.90	470	117.2	8.0	7.3	6.9/ +0.7
11/15/69	2300	1	2120	60.50	193.10	395	821.6	8.0	7.1	6.5/ +0.9
11/15/69	2300	2	1560	54.50	195.60	565	49.6	8.0	7.0	6.2/ +1.0
11/15/69	2300	3	1540	66.50	159.70	530	82.8	8.1	6.9	6.1/ +1.2
11/15/69	2300	4	2080	74.40	158.80	530	74.4	8.0	6.9	6.0/ +1.1
11/15/69	2300	6	2040	47.60	199.00	570	66.8	8.0	7.1	6.1/ +0.9
11/15/69	2300	9	4420	1920.50	1300.00	210	143.2	9.9	6.0	2.2/ +3.9
11/15/69	2300	10	3100	1947.80	1388.70	200	144.4	9.4	6.0	2.5/ +3.4
11/16/69	500	1	1420	99.70	227.40	445	578.8	8.1	6.9	5.6/ +1.2
11/16/69	500	2	1420	95.70	200.60	485	88.4	8.2	6.8	5.5/ +1.4
11/16/69	500	3	1420	97.30	170.50	485	90.8	8.1	6.8	5.5/ +1.3
11/16/69	500	4	1460	180.60	788.00	480	99.6	8.0	6.6	5.2/ +1.4
11/16/69	500	5	340	93.30	102.00	130	9.6	7.7	7.4	7.1/ +0.3
11/16/69	500	6	1320	157.60	220.70	475	92.0	8.1	6.6	5.1/ +1.5
11/16/69	500	9	4400	1627.70	535.00	10	144.8	7.7	7.3	7.0/ +0.4
11/16/69	500	10	4200	1478.80	585.20	30	148.8	7.3	6.9	6.5/ +0.4
11/16/69	500	14	2120	1449.10	1713.80	90	378.4	8.1	6.4	4.8/ +1.7
11/16/69	1100	1	1600	25.80	255.80	580	474.0	8.0	7.3	6.7/ +0.7
11/16/69	1100	2	1560	31.80	254.10	555	66.8	7.9	7.3	6.9/ +0.6
11/16/69	1100	3	1520	25.80	195.60	555	70.0	8.0	7.3	6.8/ +0.7
11/16/69	1100	4	1540	17.87	61.36	560	67.2	8.0	7.4	6.9/ +0.6
11/16/69	1100	5	352	49.60	112.00	495	15.2	7.6	7.1	6.3/ +0.5
11/16/69	1100	6	1830	20.80	369.20	580	84.0	8.0	7.4	6.9/ +0.6
11/16/69	1100	8	6000	2282.80	168.90	75	7601.0	5.9	6.3	6.7/ -0.4
11/16/69	1100	9	3900	903.90	599.90	75	510.8	8.7	6.8	4.8/ +1.9
11/16/69	1100	11	3480	635.20	601.60	110	865.6	8.5	6.7	4.8/ +1.8
11/16/69	1100	13	2000	149.10	275.90	500	76.4	8.0	6.6	5.3/ +1.4
11/16/69	1100	14	1800	61.50	40.10	185	90.4	8.2	7.4	6.6/ +0.8
11/16/69	1700	1	1440	63.60	262.50	515	758.4	7.9	7.0	6.1/ +0.9
11/16/69	1700	2	1360	53.60	264.20	450	140.8	7.9	7.1	6.6/ +0.8
11/16/69	1700	4	1320	69.50	232.40	445	132.4	8.0	7.0	6.0/ +1.0
11/16/69	1700	6	1320	268.70	158.80	460	133.6	7.9	6.4	5.1/ +1.5
11/16/69	1700	9	2320	794.00	451.40	25	106.8	7.2	7.3	7.3/ -0.1
11/16/69	1700	11	2360	545.90	401.30	65	118.9	8.2	7.0	5.8/ +1.2

245

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   DATE     TIME  LOCATION  CONDUCTIVITY    CACO3     MGCO3  ALKALINITY  SUSP.SOLIDS   PH   PHS      I/IS

 11/16/69   1700     14         1800       357.30    326.00      45          355.8     9.0  7.3    5.9/ +1.7
 11/16/69   2300      1         1880        25.80    216.50     345          340.0     8.1  7.5    7.0/ +0.6
 11/16/69   2300      4         1950        27.80    206.50     375           71.6     8.1  7.5    7.1/ +0.6
 11/16/69   2300      5          340        99.30     73.60     100           37.2     7.7  7.5    6.9/ +0.2
 11/16/69   2300      6         1040        45.70    211.50     500           96.0     8.1  7.1    6.3/ +1.0
 11/16/69   2300     14         1660        56.60     66.00     110          285.6     8.3  7.7    6.9/ +0.6

 11/17/69   1700      2         1500        17.90    202.30     525           85.2     7.9  7.5    7.1/ +0.4
 11/17/69   1700      4         1420        22.90    196.50     470          114.4     8.0  7.5    7.1/ +0.5
 11/17/69   1700      5         3500        39.70    157.20     105           37.2     7.3  7.9    8.4/ -0.6
 11/17/69   1700      8         4200      1260.50    727.30      85        17140.8  ****** ******  ********/ +0.0
 11/17/69   1700      9         5140      1071.90   1759.80      50         1605.6     6.9  6.8    6.8/ +0.1
 11/17/69   1700     10         6800      1081.80   1463.00     145         1607.6     7.0  6.4    5.7/ +0.6
 11/17/69   1700     13         5080       972.70   1646.90      60         2089.4     6.9  6.8    6.7/ +0.1
 11/17/69   1700     14         2360       625.30    309.30      65         2203.5     9.3  6.9    4.6/ +2.4

 11/18/69    800      1         1180       131.01    305.99     320          303.2     8.0  6.9    5.8/ +1.1
 11/18/69    800      2         1180       125.10    170.50      60           40.4     7.9  7.6    7.3/ +0.3
 11/18/69    800      4         1540        79.63    215.69     350           58.0     8.0  7.1    6.1/ +0.9
 11/18/69    800      5          500       111.20     55.20      40           22.4     7.5  7.8    8.1/ -0.3
 11/18/69    800      6         1520        71.46    227.10     350           62.4     8.0  7.1    6.2/ +0.9
 11/18/69    800      9         3600      1310.10    101.99     330        37411.0     8.5  5.9    3.3/ +2.6
 11/18/69    800     11         3030       893.35     39.46     350          121.6     8.4  6.0    3.7/ +2.4
 11/18/69    800     14         1700        45.66     33.46     150           98.8     8.5  7.6    6.7/ +0.9
 11/18/69   1200      1         1220        93.42    200.00     355          263.8     8.1  7.0    6.9/ +1.1
 11/18/69   1200      2         1240       197.19    173.89     345           29.6     8.1  6.9    5.9/ +1.2
 11/18/69   1200      3         1160        79.40    195.59     480           31.6     8.2  6.9    5.8/ +1.3
 11/18/69   1200      4         1200        27.79    227.39     150           47.2     8.1  7.9    7.8/ +0.2
 11/18/69   1200      5          500        81.30     90.29      95           21.2     7.7  7.6    7.2/ +0.1
 11/18/69   1200      6         1200        97.34    209.00     345           31.6     8.1  7.0    6.1/ +1.1
 11/18/69   1200      9         3100      1083.95    167.29     495           93.6     9.7  5.8    2.2/ +3.9
 11/18/69   1200     14         1670        53.60     25.08      95           93.6     8.5  7.7    7.0/ +0.8
 11/18/69   1600      1         1000       166.70    135.40     305          294.0     7.5  6.8    6.3/ +0.7
 11/18/69   1600      2         1040        65.50    205.70     325           87.6     7.7  7.2    6.9/ +0.5
 11/18/69   1600      3         1020       140.90    162.29     315           78.8     7.8  6.9    6.1/ +0.9
 11/18/69   1600      4         1060        85.40    212.30     320           91.2     8.1  7.1    6.2/ +1.0
 11/18/69   1600      5          370       103.36     56.80      95           35.2     7.4  7.5    7.2/ -0.1
 11/18/69   1600      6         1040        87.30    194.00     310           62.0     7.8  7.1    6.2/ +0.7
 11/18/69   1600      9         2040      1181.10    409.60      20           86.4     8.3  7.2    6.2/ +1.1
 11/18/69   1600     11         2460       923.40     66.90      25          103.6     8.3  7.2    6.1/ +1.1
 11/18/69   1600     14         1420       317.40    300.30      20          134.0     9.2  7.7    6.2/ +1.5
 11/18/69   2400      1          960       148.90    178.90     320          426.4     7.6  6.8    6.2/ +0.8
 11/18/69   2400      2         1000       695.10    230.10     275           61.6     7.8  6.3    4.7/ +1.5
 11/18/69   2400      4          930       123.10    175.60     330           56.4     8.2  6.9    5.6/ +1.3
 11/18/69   2400      4          940        77.42    215.70     270           42.8     8.0  7.2    6.4/ +0.8
 11/18/69   2400      5          360        59.40     70.20     100           35.6     7.4  7.5    7.4/ -0.1
 11/18/69   2400      6          940        97.30    173.90     140           58.4     7.9  7.4    6.9/ +0.5
 11/18/69   2400      9         4000      1746.80    351.10      50          128.0     6.8  6.6    6.3/ +0.2
 11/18/69   2400     11         3400      1419.30    387.00      45          115.6     7.0  6.8    6.5/ +0.2
 11/18/69   2400     14         1360       377.20  [illegible]   70           79.2     8.7  7.1    5.5/ +1.6
 343
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DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
11/19/69	200	2	1440	35.70	270.90	460	38.0	8.3	7.3	6.3/ +1.0
11/19/69	200	3	1320	37.70	257.50	430	29.2	8.3	7.3	6.3/ +1.0
11/19/69	200	14	2160	75.40	61.90	85	110.0	8.5	7.7	6.8/ +0.8
11/19/69	800	1	1480	154.00	229.10	305	335.2	8.1	6.8	5.6/ +1.3
11/19/69	800	2	1120	51.60	237.40	300	44.0	8.1	7.3	6.5/ +0.8
11/19/69	800	3	1380	117.12	175.60	285	44.0	8.3	7.0	5.7/ +1.3
11/19/69	800	6	1400	555.80	239.10	200	59.2	8.3	6.3	4.4/ +2.0
11/19/69	800	9	4700	1430.13	403.20	505	292.4	7.9	5.7	3.5/ +2.2
11/19/69	800	11	1460	1329.95	317.70	290	132.0	9.0	6.0	3.0/ +3.0
11/19/69	800	14	1980	77.40	56.80	40	74.0	8.6	8.0	7.3/ +0.6
11/19/69	1400	1	1340	65.50	229.10	370	1545.2	8.0	7.1	6.2/ +0.9
11/19/69	1400	5	#########	93.30	75.20	175	41.2	7.8	7.3	6.7/ +0.5
11/19/69	1400	10	3000	1597.90	175.60	30	708.8	7.1	6.9	6.7/ +0.2
11/19/69	1600	4	1400	43.70	48.50	445	39.6	8.4	7.2	5.0/ +1.2
11/19/69	1600	9	#########	506.20	568.50	45	2310.0	7.1	7.2	7.3/ −0.1
11/19/69	1600	13	1390	178.70	301.00	450	40.4	8.3	6.6	4.9/ +1.7
11/20/69	800	1	1400	50.60	143.80	240	335.2	8.2	7.3	6.5/ +0.9
11/20/69	800	2	1320	61.50	192.30	90	57.2	8.1	7.8	7.4/ +0.3
11/20/69	800	4	1420	51.60	210.70	205	49.8	8.4	7.3	6.2/ +1.1
11/20/69	800	5	#########	66.50	108.70	140	30.0	7.9	7.5	7.1/ +0.4
11/20/69	800	6	980	40.60	210.70	235	20.0	8.2	7.4	6.7/ +0.8
11/20/69	800	9	5400	1508.60	802.60	230	244.6	9.0	6.0	3.0/ +3.0
11/20/69	1200	1	1320	555.80	158.80	#########	1864.4	8.7	#####	######/######
11/20/69	1200	2	1420	133.10	152.20	#########	77.2	7.6	#####	######/######
11/20/69	1200	3	1400	139.00	153.80	#########	73.2	8.0	#####	######/######
11/20/69	1200	4	1420	123.10	150.50	#########	56.0	8.1	#####	######/######
11/20/69	1200	5	360	107.20	180.60	#########	26.0	7.7	#####	######/######
11/20/69	1200	6	1260	109.20	160.50	#########	61.6	7.8	#####	######/######
11/20/69	1200	9	#########	1151.30	359.50	#########	130.2	7.4	#####	######/######
11/20/69	1200	14	1340	287.80	317.70	#########	30.2	8.2	#####	######/######
11/20/69	1600	1	1040	174.70	90.30	#########	252.0	7.7	#####	######/######
11/20/69	1600	2	1140	135.00	115.40	#########	26.0	7.6	#####	######/######
11/20/69	1600	4	1160	137.00	115.40	#########	76.8	9.0	#####	######/######
11/20/69	1600	5	#########	125.10	63.50	#########	14.8	7.8	#####	######/######
11/20/69	1600	6	1160	140.90	107.00	#########	47.2	8.0	#####	######/######
11/20/69	1600	9	4000	1270.40	376.20	#########	425.0	9.6	#####	######/######
11/20/69	1600	11	3100	923.00	317.70	#########	450.0	9.6	#####	######/######
11/20/69	1600	14	1420	77.40	484.00	#########	60.0	8.5	#####	######/######
11/21/69	800	1	#########	81.40	214.00	#########	458.8	8.0	#####	######/######
11/21/69	800	3	1400	95.30	200.60	#########	24.4	8.0	#####	######/######
11/21/69	800	4	1180	55.60	279.20	#########	26.4	8.0	#####	######/######
11/21/69	800	5	400	87.30	88.60	#########	33.2	8.1	#####	######/######
11/21/69	800	6	1060	156.80	142.10	#########	26.0	8.0	#####	######/######
11/21/69	800	9	1440	486.30	#########	#########	240.2	11.3	#####	######/######
11/21/69	800	11	920	317.60	#########	#########	136.8	8.7	#####	######/######
11/21/69	800	12	1560	27.80	41.80	#########	27.2	7.7	#####	######/######
11/21/69	1200	1	1620	65.50	257.50	#########	441.2	7.9	#####	######/######
11/21/69	1200	2	1600	206.40	165.50	#########	44.8	8.0	#####	######/######

241

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DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
11/21/69	1200	3	1480	140.90	182.20	**********	21.6	8.0	*****	******/******
11/21/69	1200	4	1560	158.80	217.40	**********	38.0	8.0	*****	******/******
11/21/69	1200	5	400	135.10	51.80	**********	21.6	7.3	*****	******/******
11/21/69	1200	6	1580	91.30	6.70	**********	97.2	8.0	*****	******/******
11/21/69	1200	9	3540	1280.30	********	**********	88.0	11.0	*****	******/******
11/21/69	1200	11	2640	893.30	861.10	**********	166.0	11.0	*****	******/******
11/21/69	1200	12	1420	168.70	90.30	**********	122.4	8.6	*****	******/******
11/21/69	2000	2	1140	216.40	********	**********	178.4	8.0	*****	******/******
11/22/69	800	1	1720	41.70	********	**********	382.0	8.0	*****	******/******
11/22/69	800	2	1900	13.90	331.10	**********	54.8	7.9	*****	******/******
11/22/69	800	3	1400	11.90	277.60	**********	46.0	8.1	*****	******/******
11/22/69	800	4	1700	61.50	18.80	**********	45.6	7.3	*****	******/******
11/22/69	800	5	400	95.40	60.80	**********	31.6	7.2	*****	******/******
11/22/69	800	6	1620	35.70	********	**********	52.8	7.8	*****	******/******
11/22/69	800	9	4600	1677.30	217.40	**********	139.0	8.7	*****	******/******
11/22/69	800	11	3200	1121.50	217.40	**********	123.6	8.6	*****	******/******
11/22/69	1200	1	1600	47.60	********	**********	365.4	8.0	*****	******/******
11/22/69	1200	2	1540	47.60	302.60	**********	71.6	8.0	*****	******/******
11/22/69	1200	4	1620	45.70	********	**********	40.0	8.2	*****	******/******
11/22/69	1200	5	260	97.30	76.90	**********	32.8	7.3	*****	******/******
11/22/69	1200	6	1640	65.50	********	**********	42.4	8.1	*****	******/******
11/22/69	1200	9	1720	615.40	********	**********	50.8	8.2	*****	******/******
11/22/69	1200	11	4700	1588.00	376.20	**********	599.0	8.2	*****	******/******
11/22/69	1200	12	6000	2114.00	********	**********	10264.4	8.1	*****	******/******
11/22/69	1600	1	1700	55.60	326.00	**********	526.8	8.0	*****	******/******
11/22/69	1600	2	1760	133.70	300.30	**********	62.4	7.8	*****	******/******
11/22/69	1600	3	1720	190.60	285.60	**********	68.0	8.0	*****	******/******
11/22/69	1600	4	1380	35.70	341.10	**********	86.8	7.9	*****	******/******
11/22/69	1600	5	*********	67.50	110.40	**********	56.0	7.4	*****	******/******
11/22/69	1600	6	1760	37.70	302.60	**********	100.6	7.9	*****	******/******
11/22/69	1600	9	4400	2098.20	583.40	**********	566.8	8.3	*****	******/******
11/22/69	1600	11	3600	1171.20	232.60	**********	560.6	7.1	*****	******/******
11/22/69	1600	14	1400	704.70	********	**********	61.6	8.6	*****	******/******
11/23/69	800	1	1260	35.40	281.70	250	673.2	7.0	7.6	7.2/ +0.3
11/23/69	800	2	1300	35.40	305.50	250	30.0	8.0	7.6	7.1/ +0.4
11/23/69	800	3	1260	92.40	246.10	155	87.2	8.1	7.4	6.6/ +0.7
11/23/69	800	4	1260	28.50	228.70	175	42.8	8.2	7.8	7.4/ +0.4
11/23/69	800	4	1260	25.60	308.20	160	21.6	8.3	7.9	7.5/ +0.4
11/23/69	800	5	410	84.50	91.10	55	11.2	7.7	7.8	7.9/ -0.1
11/23/69	800	6	1640	30.50	290.90	195	67.2	8.1	7.7	7.4/ +0.4
11/23/69	800	9	5300	1305.60	1935.10	65	792.8	7.5	6.6	5.7/ +0.9
11/23/69	800	11	4600	1214.60	1271.70	65	754.8	8.0	6.7	5.3/ +1.3
11/23/69	800	14	1640	472.10	331.40	25	5410.8	9.1	7.5	5.9/ +1.6
11/23/69	1200	1	1380	106.20	246.10	205	391.2	7.9	7.2	6.4/ +0.7
11/23/69	1200	2	1300	112.10	227.80	**********	18.8	8.1	*****	******/******
11/23/69	1200	3	1260	98.40	215.40	170	30.0	8.1	7.3	6.5/ +0.8
11/23/69	1200	4	2280	796.60	323.10	500	58.8	8.1	5.9	3.8/ +2.2
11/23/69	1200	5	410	66.90	119.30	85	5.6	7.6	7.7	7.8/ -0.1

339

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
11/23/69	1200	6	1260	105.20	215.40	245	76.8	8.1	7.1	6.1/ +1.0
11/23/69	1200	9	4000	1713.20	362.10	*********	622.4	9.0	*****	******/******
11/23/69	1200	11	680	1226.20	323.10	115	318.0	8.3	6.4	4.5/ +1.9
11/23/69	1200	12	1020	531.10	352.10	20	4128.0	8.4	7.5	6.6/ +0.9
11/23/69	1600	1	1200	100.30	222.00	170	376.8	7.8	7.3	6.7/ +0.5
11/23/69	1600	2	1240	49.20	265.90	230	21.2	7.9	7.5	7.0/ +0.4
11/23/69	1600	3	1200	45.20	258.50	175	26.4	8.2	7.6	7.0/ +0.6
11/23/69	1600	4	1240	45.20	255.20	170	25.6	8.2	7.6	7.0/ +0.6
11/23/69	1600	5	420	43.30	135.90	75	20.4	7.6	8.0	8.3/ -0.4
11/23/69	1600	6	1220	82.60	237.00	130	27.6	8.1	7.5	6.8/ +0.6
11/23/69	1600	9	1020	457.10	716.70	*********	2487.2	7.8	*****	******/******
11/23/69	1600	11	1252	422.90	911.40	45	2067.6	8.1	7.3	6.5/ +0.8
11/23/69	1600	12	1660	993.30	256.80	40	4018.0	8.3	7.0	5.6/ +1.3
11/24/69	700	4	1360	104.30	178.90	245	22.3	8.0	7.1	6.2/ +0.9
11/24/69	700	11	1820	700.00	174.00	52	77.8	8.0	7.0	5.9/ +1.0
11/24/69	2300	4	1400	175.10	137.50	270	18.8	8.0	6.8	5.7/ +1.2
11/24/69	2300	11	1340	127.80	135.90	275	12708.4	7.9	6.9	6.0/ +1.0
11/25/69	700	4	1260	116.10	215.40	255	22.3	8.1	7.0	6.0/ +1.1
11/25/69	700	11	2240	885.00	215.40	*********	285.9	2.9	*****	******/******
11/25/69	1500	4	1320	64.90	227.00	330	49.6	8.0	7.2	6.3/ +0.8
11/25/69	1500	11	1500	580.00	197.70	22	203.7	7.5	7.4	7.3/ +0.1
11/25/69	2300	4	1220	70.80	261.80	230	44.5	8.0	7.3	6.6/ +0.7
11/25/69	2300	11	820	335.00	99.40	25	106.1	6.8	7.6	8.4/ 0.8
11/26/69	700	4	1280	163.30	143.30	235	30.8	8.0	6.9	5.8/ +1.1
11/26/69	700	11	1580	507.40	66.30	20	135.2	7.8	7.5	7.2/ +0.3
11/26/69	1500	4	1340	135.70	205.50	280	46.2	8.0	6.9	5.9/ +1.1
11/26/9	1500	11	960	118.00	182.30	185	35.9	8.1	7.2	6.2/ +0.9
12/26/69	2300	4	1560	131.80	197.20	230	32.5	8.1	7.0	5.9/ +1.1
11/26/69	2300	11	2040	413.10	74.60	*********	25.7	2.7	*****	******/******
11/27/69	700	4	1060	70.80	208.80	140	15.4	7.8	7.5	7.2/ +0.3
11/27/69	700	11	1440	462.20	91.10	30	102.7	7.9	7.4	6.9/ +0.5
11/27/69	1500	4	1180	30.00	222.00	225	39.4	8.0	7.6	7.1/ +0.4
11/27/69	1500	11	1920	600.00	49.70	20	114.7	7.2	7.4	7.7/ -0.2
11/27/69	2300	4	1200	31.50	258.50	215	35.9	8.1	7.7	7.2/ +0.4
11/27/69	2300	11	1620	490.00	157.40	40	320.1	7.7	7.2	6.8/ +0.5
11/28/69	700	4	1440	155.70	56.30	235	39.4	7.9	6.9	5.9/ +1.0
11/28/69	700	11	1240	245.90	33.10	65	113.0	7.0	7.3	6.7/ +0.6
11/28/69	1500	4	1480	216.00	91.00	165	32.5	8.0	6.9	5.9/ +1.1
11/28/69	1500	11	2240	550.80	74.60	27	1395.1	7.8	7.3	6.9/ +0.5
11/28/69	2300	4	1520	253.70	39.80	240	66.8	8.0	6.7	5.4/ +1.3
11/28/69	2300	11	2400	521.30	82.80	*********	63.3	2.7	*****	******/******
11/29/69	700	4	1080	143.00	112.70	255	32.5	7.8	6.9	6.1/ +0.9
12/29/69	700	11	1560	437.70	62.10	*********	54.8	4.0	*****	******/******
11/29/69	1500	4	1320	285.20	33.10	275	34.2	8.0	6.6	5.2/ +1.4

433

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DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
11/29/69	1500	11	2840	560.60	91.10	########	70.2	2.6	#####	#####/#####
11/29/69	2300	4	1680	261.60	66.30	360	56.5	7.8	6.5	5.2/ +1.3
11/29/69	2300	11	1600	403.20	116.00	270	176.3	6.8	6.5	6.2/ +0.3
11/30/69	700	4	1020	102.30	152.40	102	41.1	7.9	7.5	7.0/ +0.4
11/30/69	700	11	1540	521.30	74.60	10	501.6	7.0	7.8	8.6/ -0.8
11/30/69	1500	4	1020	123.00	199.40	140	10.3	7.7	7.2	6.8/ +0.5
11/30/69	1500	11	1440	432.70	132.60	25	356.1	7.9	7.5	7.1/ +0.4
11/30/69	2300	4	1000	93.00	152.40	180	35.9	7.9	7.2	6.6/ +0.7
11/30/69	2300	11	3480	550.80	90.40	########	54.8	2.0	####	#####/#####
12/ 1/69	700	4	880	208.50	30.80	165	27.4	7.7	6.9	6.2/ +0.8
12/ 1/69	1500	4	1120	216.40	48.10	230	29.1	7.9	6.8	5.7/ +1.1
12/ 1/69	2300	4	1140	188.80	71.20	225	18.8	7.9	6.9	5.8/ +1.0
12/ 2/69	700	4	1420	206.50	38.10	195	17.1	7.9	6.9	5.9/ +1.0
12/ 2/69	1500	4	980	210.50	53.00	130	30.8	7.8	7.1	6.3/ +0.7
12/ 2/69	2300	4	1580	204.60	33.10	250	30.8	7.8	6.8	5.7/ +1.0
- 12/ 4/69	700	4	1040	230.10	36.50	80	24.0	7.6	7.2	6.8/ +0.4
12/ 4/69	1500	4	1100	181.00	59.60	155	54.8	7.9	6.9	6.0/ +1.0
12/ 4/69	2300	4	1000	184.90	64.60	120	29.1	7.8	7.1	6.5/ +0.7
12/ 5/69	700	4	1020	240.00	66.30	210	32.5	8.1	6.8	5.5/ +1.3
12/ 5/69	700	11	820	225.20	41.00	65	393.7	10.9	7.3	3.7/ +3.6
12/ 5/69	1500	4	940	202.60	56.30	100	35.9	8.0	7.2	6.4/ +0.8
12/ 5/69	1500	11	880	157.40	124.00	60	125.0	8.4	7.5	6.6/ +0.9
12/ 5/69	2300	4	1060	175.10	92.80	145	29.1	8.1	7.1	6.1/ +1.0
12/ 5/69	2300	11	700	236.00	16.60	40	835.4	8.8	7.5	6.2/ +1.3
12/ 6/69	700	4	1180	129.80	142.50	130	35.0	8.2	7.3	6.3/ +0.9
12/ 6/69	700	11	940	236.00	8.30	65	255.1	11.0	7.3	3.6/ +3.7
12/ 6/69	1500	4	1200	143.60	167.40	155	30.8	8.4	7.2	5.9/ +1.2
12/ 6/69	1500	11	1040	245.90	91.00	95	172.9	11.3	7.1	3.0/ +4.2
12/ 6/69	2300	4	1160	116.10	172.30	185	32.5	8.4	7.2	5.9/ +1.2
12/ 6/69	2300	11	900	216.40	25.00	65	295.1	11.0	7.3	3.7/ +3.7
12/ 7/69	700	4	1140	123.90	161.00	170	35.0	8.4	7.2	5.9/ +1.2
12/ 7/69	700	11	1000	106.70	33.00	80	357.8	11.1	7.3	3.5/ +3.8
12/ 7/69	1500	4	1260	80.60	186.00	205	8.6	8.5	7.3	6.1/ +1.2
12/ 7/69	1500	11	940	177.00	8.30	70	268.8	10.9	7.4	3.9/ +3.5
12/ 7/69	2300	4	1280	84.60	219.00	225	35.9	8.5	7.2	5.9/ +1.3
12/ 7/69	2300	11	1220	206.50	58.00	115	443.4	11.4	7.1	2.8/ +4.3
12/ 8/69	700	4	1120	214.40	60.00	175	46.2	8.0	6.9	5.8/ +1.1
12/ 8/69	700	11	90	787.00	41.00	60	251.6	10.9	6.9	2.8/ +4.0
12/ 8/69	1500	4	1120	196.70	85.00	175	47.9	8.2	7.0	5.7/ +1.2
12/ 8/69	1500	11	980	196.70	33.00	65	241.4	10.8	7.4	3.9/ +3.4
12/ 8/69	2300	4	1280	183.00	80.00	220	42.8	8.2	6.9	5.6/ +1.3
12/ 8/69	2300	11	2320	551.00	17.00	175	273.9	11.4	6.5	1.7/ +4.9

525

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
12/ 9/69	700	4	1080	228.00	56.30	165	20.1	8.2	6.9	5.6/ +1.3
12/ 9/69	700	11	2200	668.30	108.00	##########	18.8	2.1	#####	######/######
12/ 9/69	1500	4	1880	671.00	62.60	##########	30.8	6.1	#####	######/######
12/ 9/69	1500	11	1160	206.50	82.80	190	20.5	7.9	6.9	5.9/ +1.0
12/ 9/69	2300	4	1720	622.00	6.60	95	220.4	10.8	6.8	2.7/ +4.0
12/ 9/69	2300	11	1200	187.00	99.40	200	20.5	8.2	6.9	5.6/ +1.3
12/10/69	700	4	1440	161.30	164.00	155	22.3	8.2	7.1	6.0/ +1.1
12/10/69	700	11	1920	708.10	33.10	##########	7.2	3.7	#####	######/######
12/10/69	1500	4	1160	234.10	51.40	170	29.1	8.2	6.9	5.6/ +1.3
12/10/69	1500	11	1720	728.00	157.00	5	44.5	7.4	3.0	8.6/ −0.6
12/10/69	2300	4	1400	190.80	86.20	205	29.1	8.2	6.9	5.6/ +1.3
12/10/69	2300	11	1440	413.10	207.00	60	58.2	8.0	7.1	5.3/ +0.9
12/11/69	700	11	2600	875.00	165.70	##########	32.5	3.3	#####	######/######
12/11/69	1500	4	1600	179.00	126.00	105	46.2	8.3	7.2	6.1/ +1.1
12/11/69	1500	11	2200	649.00	16.60	190	152.4	11.6	6.5	1.3/ +5.1
12/11/69	2300	4	1400	124.00	164.00	135	34.2	8.4	7.3	6.1/ +1.1
12/11/69	2300	11	2760	846.00	49.70	330	256.8	12.0	6.1	0.2/ +5.9
12/12/69	#####	4	1980	196.70	527.00	##########	39.4	4.8	#####	######/######
12/12/69	#####	11	1300	423.00	133.00	15	136.9	8.9	7.7	6.5/ +1.2
12/13/69	#####	4	1380	456.30	81.20	130	27.4	8.0	6.7	5.5/ +1.3
12/13/69	#####	11	3600	1003.00	107.70	80	160.9	11.2	6.6	2.1/ +4.6
12/14/69	#####	4	1920	316.70	451.00	80	41.1	7.3	7.1	7.0/ +0.2
12/14/69	#####	11	2240	1131.00	91.10	15	210.6	10.3	7.3	4.3/ +3.0
12/15/69	#####	4	1020	281.30	91.10	105	32.5	8.2	7.0	5.9/ +1.2
12/15/69	#####	11	1540	727.80	24.90	20	272.2	9.8	7.4	4.9/ +2.4
12/16/69	#####	4	1400	393.40	124.00	120	554.6	10.9	6.8	2.8/ +4.1
12/16/69	#####	11	1160	354.00	746.00	4	465.6	9.1	8.4	7.7/ +0.7
12/17/69	#####	4	1340	220.00	152.40	104	59.0	7.6	7.1	6.7/ +0.5
12/17/69	#####	11	1400	39.30	291.70	20	12.8	8.6	8.6	8.6/ -0.0
12/18/69	#####	4	1380	96.00	306.00	70	138.7	7.8	7.7	7.6/ +0.1
12/18/69	700	11	1440	384.00	99.30	85	142.1	7.7	7.0	6.3/ +0.7
12/18/69	1500	11	1720	677.00	215.00	##########	325.2	2.1	#####	######/######
12/19/69	#####	4	1380	173.10	162.00	90	59.0	7.6	7.3	7.0/ +0.3
12/19/69	#####	11	2200	915.00	33.00	20	260.2	8.2	7.3	6.4/ +0.9
12/20/69	#####	4	1420	159.30	252.00	50	41.1	7.2	7.6	8.0/ −0.4
12/20/69	#####	11	1720	1229.00	24.80	50	138.7	10.1	6.8	3.4/ +3.3
12/21/69	#####	4	1600	145.60	247.00	90	56.5	7.7	7.4	7.1/ +0.3

612

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
1/ 7/70	****	4	860	206.00	60.00	90	30.8	7.9	7.2	6.5/ +0.7
1/ 7/70	****	11	600	118.00	91.00	90	123.2	8.9	7.5	6.0/ +1.4
1/ 8/70	****	4	860	775.00	11.60	95	49.6	7.9	6.7	5.4/ +1.2
1/ 8/70	****	11	1260	413.00	41.00	230	243.1	10.8	6.5	2.3/ +4.3
1/ 9/70	****	4	1080	187.00	93.00	195	35.9	8.0	6.9	5.9/ +1.1
1/ 9/70	****	11	2440	984.00	75.00	480	15.4	11.3	5.9	0.5/ +5.4
1/10/70	****	4	1300	275.00	51.00	255	279.0	7.9	6.7	5.4/ +1.2
1/10/70	****	11	1460	610.00	108.00	30	897.0	6.9	7.3	7.6/ -0.4
1/11/70	****	4	1320	277.00	61.00	245	301.3	8.0	6.7	5.3/ +1.3
1/11/70	****	11	1000	374.00	124.00	70	558.0	8.6	7.1	5.6/ +1.5
1/12/70	****	4	1300	134.00	167.00	315	253.3	7.9	6.9	5.8/ +1.0
1/12/70	****	11	2120	964.00	66.30	60	53.1	10.4	6.8	3.2/ +3.6
1/13/70	****	4	1380	232.00	36.00	335	215.7	8.0	6.6	5.2/ +1.4
1/13/70	****	11	2200	816.00	50.00	250	30.8	11.4	6.2	1.1/ +5.2
1/14/70	****	4	1480	281.30	16.60	405	6.8	8.1	6.5	4.8/ +1.7
1/14/70	****	11	1800	481.90	198.80	15	68.5	7.3	7.7	8.0/ -0.4
1/15/70	****	11	1680	501.60	116.00	15	268.8	6.0	7.6	9.3/ -1.6
1/16/70	****	4	1240	224.00	61.30	200	8.6	7.7	6.8	5.9/ +0.9
1/16/70	****	11	2160	954.00	33.10	60	249.2	10.1	6.8	3.5/ +3.3
1/17/70	****	4	1680	253.70	124.30	290	18.8	7.8	6.6	5.5/ +1.2
1/17/70	****	11	2840	708.10	215.40	*********	35.9	1.8	****	*****/*****
1/18/70	****	4	2160	539.00	169.00	245	313.3	8.0	6.4	4.8/ +1.6
1/18/70	****	11	1750	617.00	74.60	150	313.3	10.9	6.6	2.2/ +4.3
1/19/70	****	4	1620	240.00	84.50	435	46.2	8.2	6.5	4.8/ +1.7
1/19/70	****	11	1540	373.70	33.10	180	629.4	11.3	6.7	2.1/ +4.6
1/20/70	****	4	1580	19.70	260.10	400	31.3	7.9	7.6	7.3/ +0.3
1/20/70	****	11	1100	157.40	33.10	135	662.3	10.9	7.1	3.4/ +3.8
1/21/70	****	4	980	192.80	57.00	195	*********	8.1	6.9	5.7/ +1.2
1/21/70	****	11	1680	110.10	1.70	260	688.8	11.6	7.0	2.4/ +4.6
1/21/70	****	11	4500	116.00	619.60	1585	*********	8.9	6.3	3.7/ +2.6
1/22/70	****	4	1040	250.00	75.00	235	27.0	8.0	6.7	5.5/ +1.3
1/22/70	300	11	940	425.00	124.00	20	2662.9	8.8	7.6	6.4/ +1.2
1/23/70	****	4	1000	226.00	50.00	170	22.4	7.9	6.9	5.9/ +1.0
1/24/70	****	4	1340	250.00	70.00	375	16.4	8.0	6.5	5.1/ +1.5

478

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
1/24/70	*****	11	680	236.00	41.00	30	208.0	8.8	7.6	6.5/ +1.2
1/25/70	*****	4	1840	234.00	98.00	415	********	8.0	6.5	5.0/ +1.5
1/25/70	*****	11	1480	384.00	91.00	100	********	7.7	6.9	6.2/ +0.8
1/26/70	*****	4	1840	258.00	35.00	425	********	7.8	6.5	5.3/ +1.3
1/26/70	*****	11	1180	275.00	66.00	40	175.5	7.7	7.5	7.2/ +0.2
1/27/70	*****	4	1720	230.00	61.00	455	11.0	8.0	6.5	4.9/ +1.5
1/27/70	*****	11	1500	443.00	33.00	195	178.4	11.3	6.6	1.9/ +4.7
1/28/70	*****	4	2560	285.00	15.00	690	53.2	8.0	6.2	4.4/ +1.8
1/28/70	*****	11	960	197.00	17.00	115	337.2	11.0	7.1	3.2/ +3.9
1/29/70	*****	4	2080	281.00	18.00	670	77.0	8.0	6.2	4.4/ +1.8
1/29/70	*****	11	530	177.00	41.00	45	102.7	8.1	7.6	7.1/ +0.5
1/30/70	*****	4	2120	209.00	33.00	630	106.1	7.9	6.2	4.5/ +1.7
1/30/70	*****	11	1100	197.00	17.00	35	71.9	9.8	7.6	5.5/ +2.2
1/31/70	*****	4	2670	283.00	26.50	800	73.6	8.1	6.1	4.2/ +2.0
1/31/70	*****	11	1440	49.00	95.00	30	821.7	8.3	8.3	8.3/ +0.0
2/ 1/70	*****	11	1200	68.40	58.00	5	1160.2	****	****	*****/ 0.0
2/ 2/70	*****	4	2300	269.00	23.20	570	42.3	8.2	6.3	4.4/ +1.9
2/ 2/70	*****	11	940	148.00	41.40	10	319.1	8.3	8.3	8.3/ 0.0
2/ 3/70	*****	4	2480	287.00	18.20	545	31.7	8.1	6.3	4.5/ +1.8
2/ 3/70	*****	11	1070	88.50	33.10	20	21.9	8.9	8.2	7.5/ +0.7
2/ 4/70	*****	4	2300	273.00	33.10	555	115.0	7.9	6.3	4.7/ +1.6
2/ 4/70	*****	11	700	98.40	74.60	35	84.6	8.8	7.9	7.1/ +0.9
2/ 5/70	*****	4	1920	267.50	30.80	400	37.7	8.0	6.5	4.9/ +1.5
2/ 5/70	*****	11	1030	127.90	16.57	100	131.9	11.0	7.4	3.7/ +3.6
2/ 6/70	*****	4	1620	141.60	16.57	375	112.5	8.9	6.7	4.6/ +2.2
2/ 6/70	*****	11	1600	98.40	58.00	370	54.4	9.0	6.9	4.8/ +2.1
2/ 7/70	*****	4	1880	269.50	8.30	565	25.8	7.7	6.3	4.9/ +1.4
2/ 7/70	*****	11	1480	127.90	24.90	230	62.1	11.2	7.0	2.8/ +4.2
2/ 8/70	*****	4	1600	194.70	33.14	440	38.0	7.7	6.5	5.4/ +1.2
2/ 8/70	*****	11	1440	118.00	124.29	235	78.6	11.4	7.0	2.7/ +4.4
2/ 9/70	*****	4	1700	238.00	44.74	495	50.7	7.8	6.4	5.0/ +1.4
2/ 9/70	*****	11	1720	226.20	99.42	********	57.0	2.2	****	*****/*****
2/10/70	*****	4	1840	230.00	24.90	520	73.6	8.0	6.4	4.8/ +1.6

561

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
2/10/70	*****	4	1840	230.00	24.90	520	73.6	8.0	6.4	4.8/ +1.6
2/10/70	*****	4	1080	226.00	3.30	320	107.8	8.0	6.6	5.2/ +1.4
2/10/70	*****	11	1080	147.00	66.28	425	57.0	7.9	6.7	5.5/ +1.2
2/11/70	*****	4	1200	240.00	23.50	375	42.3	7.9	6.5	5.2/ +1.4
2/11/70	*****	11	1040	167.00	92.80	300	23.3	7.9	6.8	5.7/ +1.1
2/12/70	*****	4	1020	246.00	49.00	330	12.7	8.2	6.6	5.0/ +1.6
2/12/70	*****	11	776	148.00	99.40	210	54.9	8.7	7.0	5.3/ +1.7
2/13/70	*****	11	810	167.20	82.90	180	71.9	8.6	7.0	5.4/ +1.6
2/14/70	*****	4	1800	305.00	25.40	425	4.3	8.2	6.4	4.6/ +1.8
2/14/70	*****	11	810	138.00	91.10	205	31.7	8.7	7.0	5.4/ +1.7
2/15/70	*****	4	1830	311.00	25.40	425	21.1	8.3	6.4	4.5/ +1.9
2/15/70	*****	11	760	148.00	82.90	195	27.4	8.7	7.0	5.3/ +1.7
2/16/70	*****	4	1780	248.00	100.00	480	19.0	8.2	6.4	4.7/ +1.8
2/16/70	*****	11	1000	177.00	74.60	250	50.7	8.6	6.8	5.1/ +1.8
2/17/70	*****	4	1640	47.20	262.00	420	54.8	8.2	7.2	6.2/ +1.0
2/17/70	*****	11	1000	167.00	74.60	260	72.1	8.6	6.8	5.1/ +1.8
2/18/70	*****	11	970	177.00	82.90	245	116.2	8.4	6.9	5.3/ +1.5
2/22/70	*****	4	1540	41.30	288.00	380	19.0	*****	*****	******/ 0.0
2/23/70	*****	4	2220	316.00	3.90	610	135.2	8.5	6.2	3.9/ +2.3
2/24/70	*****	4	2060	315.00	60.70	605	**********	8.3	6.2	4.1/ +2.1
2/24/70	*****	11	1090	73.60	*********	275	**********	9.9	*****	******/******
2/25/70	*****	4	2040	350.00	*********	275	**********	8.6	*****	******/******
2/25/70	*****	11	840	167.00	*********	520	**********	9.3	*****	******/******
2/26/70	*****	11	900	31.50	*********	165	**********	9.4	*****	******/******
2/28/70	*****	4	1360	157.00	7.90	140	**********	8.6	7.1	5.6/ +1.5
3/ 1/70	*****	4	1400	260.00	38.10	450	**********	8.5	6.4	4.3/ +2.1
3/ 2/70	*****	4	380	*********	*********	125	**********	8.3	*****	******/******
3/ 2/70	*****	11	1780	*********	*********	470	**********	8.7	*****	******/******
3/ 3/70	*****	4	1890	*********	*********	500	**********	*****	*****	******/ 0.0
3/ 3/70	*****	11	330	*********	*********	100	**********	*****	*****	******/ 0.0
3/ 4/70	*****	4	2000	*********	*********	510	**********	8.3	*****	******/******
3/ 4/70	*****	11	1460	*********	*********	100	**********	10.0	*****	******/******

543

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
3/ 5/70	******	4	2560	*********	********	205	**********	8.4	*****	******/******
3/ 5/70	******	11	1680	*********	********	65	**********	9.0	*****	******/******
3/11/70	******	4	4600	*********	********	935	**********	8.9	*****	******/******
3/11/70	******	11	3760	*********	********	450	**********	9.8	*****	******/******
3/12/70	******	4	4600	*********	********	570	**********	8.9	*****	******/******
3/12/70	******	11	3200	*********	********	415	**********	9.9	*****	******/******
3/17/70	******	4	3960	316.00	209.40	555	**********	8.3	6.3	4.3/ +2.0
3/17/70	******	11	3560	725.00	10.00	90	**********	9.0	6.7	4.4/ +2.3
3/18/70	******	4	3500	286.00	275.90	570	**********	8.4	6.3	4.2/ +2.1
3/18/70	******	11	3320	576.00	99.40	90	**********	8.3	6.8	5.3/ +1.5
3/19/70	******	4	440	218.00	358.00	605	**********	8.5	6.4	4.3/ +2.1
3/19/70	******	11	3680	318.00	107.70	100	**********	8.5	7.0	5.5/ +1.5
3/20/70	******	4	3540	208.00	250.50	435	**********	8.3	6.4	4.6/ +1.9
3/20/70	******	11	3900	476.00	49.70	15	**********	8.5	7.7	6.8/ +0.8
3/22/70	******	4	3220	208.00	280.00	385	**********	8.4	6.6	4.8/ +1.8
3/22/70	******	11	3220	486.00	24.90	175	**********	10.6	6.6	2.6/ +4.0
3/23/70	******	4	3300	204.00	211.40	530	**********	8.3	6.3	4.4/ +2.0
3/23/70	******	11	3100	427.00	24.90	110	**********	10.3	6.8	3.4/ +3.5
3/24/70	******	4	3280	290.00	213.30	370	**********	8.1	6.5	4.9/ +1.6
3/24/70	******	11	3220	526.00	24.90	140	**********	10.7	6.7	2.6/ +4.0
3/30/70	******	4	**********	250.00	220.00	660	**********	8.5	6.3	4.1/ +2.2
3/30/70	******	11	**********	109.00	24.90	55	**********	8.9	7.4	6.0/ +1.5
3/31/70	******	4	4200	236.00	203.50	575	**********	8.5	6.4	4.3/ +2.1
3/31/70	******	11	3200	268.00	49.70	160	**********	10.7	6.8	3.0/ +3.9
4/ 1/70	******	4	4000	*********	232.10	160	**********	8.5	*****	******/******
4/ 1/70	******	11	2160	210.00	140.80	220	**********	8.3	6.8	5.4/ +1.5
4/ 2/70	******	4	2880	187.00	27.40	455	**********	8.5	6.5	4.6/ +2.0
4/ 2/70	******	11	2660	98.00	107.70	175	**********	9.0	7.2	5.5/ +1.8
4/ 5/70	******	4	2120	136.00	137.30	43	**********	8.2	7.7	7.3/ +0.5
4/ 5/70	******	11	3140	480.00	33.20	40	**********	8.6	7.2	5.9/ +1.4
4/ 6/70	******	4	2860	226.00	152.60	355	**********	8.3	6.6	4.9/ +1.7
4/ 6/70	******	11	3300	790.00	662.80	25	**********	8.8	7.3	5.7/ +1.5
4/ 7/70	******	4	1400	94.00	326.80	395	**********	8.2	6.9	5.7/ +1.3

626

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
4/ 7/70	#####	11	2760	980.00	49.30	100	#########	10.7	6.6	2.4/ +4.1
4/ 3/70	#####	4	3000	174.00	197.20	400	#########	8.3	6.7	5.0/ +1.6
4/ 8/70	#####	11	3080	700.00	49.70	95	#########	10.2	6.7	3.2/ +3.5
4/ 9/70	#####	4	#########	########	########	#########	#########	#####	#####	#####/ 0.0
4/ 9/70	#####	11	2020	470.00	24.80	295	#########	11.2	6.4	1.5/ +4.8
4/13/70	#####	4	3220	212.00	147.40	370	#########	8.4	6.6	4.8/ +1.8
4/13/70	#####	11	2900	560.00	215.00	440	#########	10.2	6.1	2.1/ +4.1
4/14/70	#####	4	1880	340.00	111.00	145	#########	8.2	6.8	5.4/ +1.4
4/14/70	#####	11	3400	1020.00	16.60	285	#########	11.3	6.1	0.9/ +5.2
4/15/70	#####	4	1090	232.00	80.00	160	#########	7.5	6.9	6.4/ +0.6
4/15/70	#####	11	2040	290.00	166.00	240	#########	8.3	6.7	5.1/ +1.6
4/16/70	#####	4	1960	232.00	109.00	945	#########	8.4	6.2	3.9/ +2.2
4/16/70	#####	11	2000	420.00	99.40	420	#########	8.0	6.3	4.5/ +1.7
4/19/70	#####	4	#########	########	########	#########	#########	#####	#####	#####/ 0.0
4/19/70	#####	11	2560	840.00	50.00	870	#########	11.5	5.7	-0.2/ +5.8
4/20/70	#####	4	1600	292.00	74.50	285	#########	8.2	6.6	5.0/ +1.6
4/20/70	#####	11	4100	1370.00	16.60	460	#########	11.6	5.8	-0.1/ +5.8
4/21/70	#####	4	2040	158.00	109.00	315	#########	8.2	6.8	5.4/ +1.4
4/21/70	#####	11	3700	1030.00	41.40	835	#########	11.9	5.6	-0.7/ +6.3
4/27/70	#####	4	2220	190.00	364.50	945	#########	8.3	6.3	4.2/ +2.0
4/27/70	#####	11	8200	3540.00	########	2490	#########	11.9	#####	######/######
4/28/70	#####	4	3500	336.00	123.00	460	#########	8.4	6.3	4.3/ +2.1
4/28/70	#####	11	10400	3380.00	33.10	1080	#########	11.8	5.0	-1.8/ +6.8
4/29/70	#####	4	3500	414.00	96.50	225	#########	8.0	6.5	5.1/ +1.5
4/29/70	#####	11	7700	2080.00	58.00	795	#########	11.9	5.3	-1.2/ +6.5
4/30/70	#####	4	3040	226.00	99.40	295	#########	8.2	6.7	5.2/ +1.5
4/30/70	#####	11	7100	2140.00	273.00	#########	#########	2.9	#####	######/######
5/ 4/70	#####	4	2520	176.00	136.00	225	#########	8.3	6.9	5.5/ +1.4
5/ 4/70	#####	11	8860	2940.00	116.00	325	#########	2.4	5.6	8.8/ -3.2
5/ 5/70	#####	4	2280	360.00	104.00	130	#########	8.3	6.8	5.4/ +1.5
5/ 5/70	#####	11	5320	1440.00	24.80	415	#########	12.5	5.8	-0.9/ +6.7
5/ 6/70	#####	4	1840	250.00	114.00	170	#########	8.4	6.9	5.4/ +1.5
5/ 7/70	#####	4	3050	162.00	149.00	470	#########	8.6	6.6	4.6/ +2.0

709

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
5/ 7/70	******	11	2560	240.00	16.50	115	**********	10.9	7.0	3.2/ +3.9
5/11/70	******	4	2800	126.00	133.00	310	**********	8.5	6.9	5.3/ +1.6
5/11/70	******	11	10200	1190.00	16.50	1715	**********	12.6	5.2	-2.1/ +7.4
5/12/70	******	4	2700	152.00	114.00	420	**********	8.4	6.7	5.0/ +1.7
5/12/70	******	11	10200	2436.00	41.40	2180	**********	12.2	4.8	-2.5/ +7.4
5/13/70	******	4	2720	114.00	139.00	775	**********	8.9	6.5	4.2/ +2.4
5/13/70	******	11	2500	50.00	99.40	740	**********	11.1	6.9	2.7/ +4.2
5/14/70	******	4	**********	144.00	118.00	295	**********	******	******	******/ 0.0
5/14/70	******	11	**********	170.00	33.10	10	**********	******	******	******/ 0.0
5/17/70	******	4	2640	116.00	156.00	385	**********	8.2	6.8	5.5/ +1.4
5/17/70	******	11	5840	1430.00	24.80	1480	**********	12.0	5.2	-1.5/ +6.8
5/18/70	******	4	2620	102.00	161.00	375	**********	8.4	6.9	5.4/ +1.5
5/18/70	******	11	9400	1970.00	16.50	2400	**********	12.1	4.9	-2.3/ +7.2
5/24/70	******	4	3700	190.00	147.50	465	**********	8.6	6.6	4.5/ +2.0
5/24/70	******	11	5980	230.00	16.60	695	**********	12.5	6.3	0.1/ +6.2
5/25/70	******	4	3520	172.00	**********	595	**********	8.8	******	******/******
5/25/70	******	11	7000	810.00	91.10	1675	**********	12.9	5.4	-2.1/ +7.5
5/26/70	******	4	3020	190.00	143.00	610	**********	8.8	6.7	4.6/ +2.1
5/26/70	******	11	6100	1200.00	24.90	1840	**********	12.9	5.2	-2.5/ +7.7
5/27/70	******	4	3900	132.00	134.20	690	**********	8.5	6.5	4.6/ +2.0
5/27/70	******	11	3400	50.00	33.10	525	**********	12.0	7.0	2.0/ +5.0
5/28/70	******	4	3720	104.00	149.00	585	**********	8.7	6.7	4.7/ +2.0
5/28/70	******	11	1780	50.00	41.40	200	**********	10.4	7.4	4.5/ +3.0
5/30/70	******	4	2980	98.00	99.40	240	**********	9.0	7.1	5.2/ +1.9
5/30/70	******	11	7600	284.00	33.50	1765	**********	12.9	5.8	-1.3/ +7.1
5/31/70	******	4	2960	108.00	107.90	165	**********	8.9	7.2	5.6/ +1.7
5/31/70	******	11	7600	164.00	16.50	1215	**********	12.9	6.2	-0.6/ +6.7
6/ 1/70	******	4	3100	138.00	89.50	280	**********	8.5	6.9	5.3/ +1.6
6/ 1/70	******	11	7800	1940.00	16.60	2040	**********	12.8	5.0	-2.9/ +7.8
6/ 2/70	******	4	3500	156.00	139.20	40	**********	7.8	7.7	7.6/ +0.1
6/ 2/70	******	11	8100	1950.00	49.50	1505	**********	12.8	5.1	-2.6/ +7.7
6/ 3/70	******	4	3600	88.00	149.10	30	**********	8.6	8.1	7.5/ +0.5
6/ 3/70	******	11	7600	1790.00	24.80	1250	**********	12.7	5.2	-2.3/ +7.5
6/ 4/70	******	4	3700	64.00	175.60	**********	**********	8.7	******	******/******

792

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
6/ 4/70	******	4	3700	84.00	175.60	**********	**********	8.7	*****	******/******
6/ 4/70	******	11	4200	550.00	315.00	340	**********	12.3	6.3	0.2/ +6.0
6/ 5/70	******	4	9000	124.00	121.00	605	**********	8.6	6.6	4.6/ +2.0
6/ 5/70	******	11	8400	820.00	331.40	1105	**********	12.4	5.6	-1.2/ +6.8
6/ 6/70	******	4	8400	71.50	122.60	710	**********	8.8	6.8	4.7/ +2.0
6/ 6/70	******	11	8400	1460.00	13.70	1875	**********	12.3	5.1	-2.1/ +7.2
6/ 7/70	******	4	4100	54.00	151.80	175	**********	8.9	7.5	6.1/ +1.4
6/ 7/70	******	11	7800	1240.00	41.40	1225	**********	12.5	5.4	-1.8/ +7.1
6/ 8/70	******	4	4100	93.00	125.90	1300	**********	8.7	6.4	4.1/ +2.3
6/ 8/70	******	11	7400	590.00	248.50	1030	**********	12.6	5.8	-1.1/ +6.8
6/ 9/70	******	4	4600	62.00	87.80	215	**********	8.8	7.3	5.9/ +1.5
6/ 9/70	******	11	4400	40.00	**********	150	**********	12.0	*****	******/******
6/13/70	******	4	4650	230.30	137.10	20	**********	8.6	7.8	7.1/ +0.8
6/13/70	******	11	6100	8960.00	26.80	550	**********	12.5	4.9	-2.8/ +7.6
6/14/70	******	4	4500	126.00	182.30	475	**********	8.4	6.7	5.0/ +1.7
6/14/70	******	11	8200	2280.00	64.00	885	**********	12.5	5.3	-2.0/ +7.2
6/17/70	******	4	5000	90.00	82.90	525	**********	8.6	6.8	5.0/ +1.8
6/17/70	******	11	6400	100.00	64.50	465	**********	12.4	6.8	1.2/ +5.6
6/18/70	******	4	4050	102.00	214.90	420	**********	8.7	6.9	5.0/ +1.8
6/18/70	******	11	2120	70.00	165.50	240	**********	9.0	7.3	5.5/ +1.7
6/19/70	******	4	1620	190.00	139.20	390	**********	8.7	6.6	4.6/ +2.1
6/19/70	******	11	1580	620.00	41.40	1535	**********	12.4	5.5	-1.3/ +6.9
6/20/70	******	4	1720	114.00	121.00	505	**********	8.7	6.7	4.8/ +2.0
6/20/70	******	11	3400	119.00	41.40	165	**********	12.5	7.2	1.8/ +5.3
6/21/70	******	4	2600	124.00	139.30	170	**********	8.5	7.2	5.8/ +1.3
6/21/70	******	11	7800	1650.00	58.00	1665	**********	12.5	5.1	-2.3/ +7.4
6/22/70	******	4	2360	160.00	175.00	290	**********	8.5	6.8	5.2/ +1.7
6/22/70	******	11	6400	580.00	818.00	1500	**********	12.5	5.6	-1.3/ +6.9
6/23/70	******	4	2920	162.00	177.30	345	**********	8.5	6.8	5.0/ +1.7
6/23/70	******	11	3900	590.00	8.30	970	**********	12.0	5.8	-0.5/ +6.2
6/24/70	******	4	3300	138.00	243.60	590	**********	8.2	6.6	5.0/ +1.6
6/24/70	******	11	3200	940.00	41.40	625	**********	11.4	5.8	0.2/ +5.6
6/25/70	******	4	3550	254.00	127.60	10	**********	8.3	8.1	7.9/ +0.2
6/25/70	******	11	2520	160.00	240.00	510	**********	8.8	6.6	4.4/ +2.2

676

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
6/26/70	******	4	2160	103.19	185.60	435	*********	8.5	6.8	5.2/ +1.7
6/26/70	******	11	4320	580.00	66.30	9	*********	12.0	7.8	3.6/ +4.2
6/27/70	******	4	2840	162.00	130.90	245	*********	8.6	6.9	5.2/ +1.7
6/27/70	******	11	8000	1050.00	57.90	1320	*********	12.6	5.4	-1.8/ +7.2
6/28/70	******	4	3420	126.00	168.70	415	*********	8.5	6.8	5.1/ +1.7
6/28/70	******	11	8400	346.00	58.00	125	*********	12.2	6.9	1.5/ +5.3
7/ 2/70	******	4	3100	156.00	192.20	285	*********	8.5	6.9	5.2/ +1.6
7/ 2/70	******	11	3650	68.00	49.70	615	*********	11.5	6.8	2.2/ +4.7
7/ 3/70	******	4	3560	164.00	193.80	400	*********	8.6	6.7	4.8/ +1.9
7/ 3/70	******	11	2450	56.00	58.00	555	*********	10.8	7.0	3.1/ +3.8
7/ 5/70	******	4	2800	8.00	175.60	355	*********	8.6	8.0	7.5/ +0.6
7/ 5/70	******	11	600	1480.00	141.00	1600	*********	12.5	5.2	-2.2/ +7.3
7/ 6/70	******	11	2980	58.00	175.60	365	*********	8.8	7.2	5.5/ +1.6
7/ 6/70	******	11	7600	175.00	16.50	1895	*********	12.5	6.0	-0.6/ +6.5
7/ 7/70	******	4	300	134.00	26.50	190	*********	8.5	7.1	5.6/ +1.4
7/ 7/70	******	11	6400	1090.00	828.50	1330	*********	12.5	5.4	-1.7/ +7.1
7/ 8/70	******	4	2800	214.00	154.10	220	*********	8.4	6.8	5.3/ +1.6
7/ 8/70	******	11	3100	590.00	16.60	635	*********	12.1	5.9	-0.2/ +6.2
7/ 9/70	******	4	3550	468.00	38.10	490	*********	8.3	6.2	4.0/ +2.1
7/ 9/70	******	11	2040	370.00	66.30	*********	*********	8.7	*****	******/******
7/10/70	******	4	3350	212.00	222.00	420	*********	8.4	6.6	4.7/ +1.8
7/10/70	******	11	3900	110.00	173.80	55	*********	12.1	7.7	3.3/ +4.4
7/11/70	******	4	600	298.00	59.70	625	*********	8.9	6.2	3.6/ +2.7
7/11/70	******	11	10200	850.00	132.60	1250	*********	12.4	5.5	-1.4/ +6.9
7/12/70	******	4	5600	702.00	478.90	135	*********	8.3	6.6	4.8/ +1.7
7/12/70	******	11	9400	3630.00	323.10	110	*********	12.1	6.0	-0.2/ +6.1
7/13/70	******	4	5100	1148.00	84.50	*********	*********	8.3	*****	******/******
7/13/70	******	11	10040	39.30	33.14	790	*********	12.1	6.9	1.8/ +5.2
7/14/70	******	4	4500	996.00	188.90	*********	*********	7.9	*****	******/******
7/14/70	******	11	5650	1930.00	59.00	635	*********	12.3	5.5	-1.4/ +6.8
7/15/70	******	4	2880	488.00	207.10	15	*********	8.2	7.7	7.1/ +0.5
7/15/70	******	11	4500	720.00	49.70	355	*********	11.7	6.1	0.6/ +5.6
7/16/70	******	4	2520	160.00	74.50	135	*********	8.5	7.2	5.8/ +1.3

759

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	1/IS
7/16/70	*****	11	1160	130.00	356.20	275	*********	8.2	7.0	5.7/ +1.2
7/17/70	*****	4	2800	264.00	59.60	445	*********	8.5	6.4	4.4/ +2.1
7/17/70	*****	11	1140	130.00	41.40	430	*********	9.0	6.7	4.4/ +2.3
7/18/70	*****	4	1800	********	********	********	*********	8.5	*****	*****/*****
7/18/70	*****	11	1600	********	********	********	*********	9.2	*****	*****/*****
7/20/70	*****	4	820	102.00	106.60	255	*********	8.5	7.1	5.6/ +1.4
7/20/70	*****	11	3840	360.00	50.70	13355	*********	12.5	4.8	-2.8/ +7.7
7/21/70	*****	4	1220	190.00	121.90	245	*********	8.4	6.8	5.3/ +1.6
7/21/70	*****	11	2800	240.00	59.20	655	*********	12.3	6.3	0.3/ +6.0
7/22/70	*****	4	1960	198.00	66.10	245	*********	8.7	6.8	4.9/ +1.9
7/22/70	*****	11	1180	120.00	42.30	195	*********	10.7	7.1	3.5/ +3.6
7/23/70	*****	4	1940	134.00	191.30	265	*********	8.5	7.0	5.4/ +1.5
7/23/70	*****	11	1160	120.00	169.30	55	*********	9.7	7.7	5.7/ +2.0
7/24/70	*****	4	2500	392.00	198.10	160	*********	8.2	6.7	5.3/ +1.5
7/24/70	*****	11	3050	1080.00	541.70	5	*********	7.4	7.8	8.2/ -0.4
7/25/70	*****	4	2240	220.00	401.20	65	*********	9.8	7.4	5.0/ +2.4
7/25/70	*****	11	2180	760.00	110.00	595	*********	9.7	5.9	2.1/ +3.8
7/27/70	*****	4	2540	198.00	204.90	390	*********	8.7	6.9	5.1/ +1.8
7/27/70	*****	11	2240	470.00	59.30	220	*********	11.6	6.5	1.4/ +5.1
7/29/70	*****	4	2990	79.00	201.50	335	*********	8.8	7.1	5.4/ +1.7
7/29/70	*****	11	2720	560.00	93.10	600	*********	12.2	6.0	-0.2/ +6.2
7/30/70	*****	4	2760	192.00	199.80	355	*********	8.8	6.9	5.1/ +1.9
7/30/70	*****	11	5100	2510.00	152.40	585	*********	11.9	5.4	-1.1/ +6.5
7/31/70	*****	4	3160	240.00	121.90	220	*********	8.6	6.8	5.0/ +1.8
7/31/70	*****	11	3700	1430.00	59.80	285	*********	11.5	5.9	0.4/ +5.6
8/ 1/70	*****	4	2650	118.00	326.70	90	*********	8.3	7.5	6.7/ +0.8
8/ 1/70	*****	4	2940	380.00	529.00	295	*********	8.2	6.5	4.8/ +1.7
8/ 1/70	*****	11	4600	1930.00	8.40	1305	*********	12.4	5.2	-2.1/ +7.2
8/ 1/70	*****	11	4800	2030.00	25.40	1665	*********	12.3	5.0	-2.2/ +7.3
8/ 2/70	*****	4	3650	228.00	347.00	460	*********	8.2	6.5	4.8/ +1.7
8/ 2/70	*****	11	5700	1690.00	8.40	1655	*********	12.2	5.1	-2.0/ +7.1
8/ 3/70	*****	4	2940	194.00	370.00	370	*********	8.1	6.7	5.3/ +1.4
8/ 3/70	*****	11	4680	1220.00	25.40	1290	*********	12.1	5.4	-1.4/ +6.7
8/ 4/70	*****	4	3700	184.00	336.00	460	********	8.3	6.6	4.9/ +1.7

843

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	1/IS
8/ 4/70	****	11	3400	640.00	16.93	530	*********	11.8	6.0	0.2/ +5.8
8/ 5/70	****	4	3420	1380.00	221.00	520	*********	8.2	5.6	2.9/ +2.6
8/ 5/70	****	11	2960	690.00	8.50	340	*********	11.6	6.2	0.7/ +5.4
8/ 7/70	****	4	2640	210.00	169.30	445	*********	8.2	6.5	4.9/ +1.7
8/ 7/70	****	11	2550	480.00	211.60	20	*********	10.3	7.5	4.8/ +2.8
8/ 8/70	****	4	3280	216.00	230.20	400	*********	8.3	6.6	4.9/ +1.7
8/ 8/70	****	11	1620	220.00	25.40	50	*********	9.4	7.4	5.5/ +2.0
8/11/70	****	4	2900	132.00	237.00	365	*********	8.5	6.8	5.2/ +1.7
8/11/70	****	11	4300	780.00	42.30	890	*********	11.7	5.7	-0.3/ +6.0
8/12/70	****	11	1380	40.00	84.65	405	*********	8.1	7.3	6.4/ +0.8
8/13/70	****	4	1480	230.00	217.50	65	*********	8.3	7.3	6.4/ +1.0
8/13/70	****	11	1300	250.00	33.80	405	*********	9.9	6.5	3.1/ +3.4
8/14/70	****	4	2540	880.00	284.00	365	*********	8.3	6.0	3.8/ +2.3
8/14/70	****	11	3490	720.00	16.93	615	*********	11.5	5.9	0.3/ +5.6
8/16/70	****	4	3190	46.00	330.00	365	*********	8.1	7.3	6.5/ +0.8
8/16/70	****	11	3550	960.00	8.50	1145	*********	11.5	5.5	-0.5/ +6.0
8/17/70	****	4	2980	230.00	220.00	440	*********	8.3	6.5	4.7/ +1.8
8/17/70	****	11	3580	810.00	84.60	1235	*********	11.5	5.5	-0.4/ +6.0
8/18/70	****	4	2640	112.00	333.00	430	*********	8.3	6.8	5.4/ +1.5
8/18/70	****	11	4480	720.00	25.40	865	*********	11.4	5.7	0.1/ +5.7
8/19/70	****	4	2510	200.00	198.00	350	*********	8.2	6.7	5.1/ +1.5
8/20/70	****	4	1560	196.00	221.00	340	*********	8.5	6.7	4.9/ +1.8
8/20/70	****	11	2100	170.00	25.40	185	*********	10.8	7.0	3.2/ +3.8
8/21/70	****	4	3100	234.00	309.80	850	*********	7.9	6.2	4.6/ +1.7
8/21/70	****	11	1640	140.00	93.10	80	*********	10.1	7.4	4.8/ +2.7
8/22/70	****	4	3020	296.00	284.40	820	*********	8.3	6.1	4.0/ +2.2
8/22/70	****	11	2820	170.00	16.93	215	*********	11.0	6.9	2.8/ +4.1
8/23/70	****	4	3320	220.00	274.30	745	*********	8.2	6.3	4.4/ +1.9
8/23/70	****	11	3760	390.00	33.90	545	*********	11.4	6.2	1.0/ +5.2
8/24/70	****	4	2660	268.00	171.00	385	*********	8.6	6.5	4.4/ +2.1
8/24/70	****	11	2220	110.00	3.30	220	*********	11.0	7.1	3.1/ +3.9
8/25/70	****	4	3560	216.00	292.90	730	*********	8.2	6.3	4.5/ +1.9
8/25/70	****	11	3700	630.00	42.30	740	*********	11.6	5.9	0.1/ +5.7

926

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    DATE    TIME  LOCATION  CONDUCTIVITY    CACO3    MGCO3  ALKALINITY  SUSP.SOLIDS   PH   PHS      I/IS

   8/26/70  #####     4          3060      230.00   181.20     630      ##########    8.1   6.4    4.6/ +1.7   *
   8/26/70  #####    11          4320      790.00     8.50    1075      ##########   11.6   5.6   -0.4/ +6.0   *

   8/27/70  #####     4          2600      190.00   194.70     420      ##########    8.1   6.6    5.1/ +1.5   *
   8/27/70  #####    11      #########     600.00    16.93    1065      ##########   11.8   5.7   -0.4/ +6.1   *

   8/28/70  #####    11          7000     1470.00     8.50    1735      ##########   13.2   5.1   -2.9/ +8.1   *

   8/29/70  #####    11          6800     1310.00    33.90    1410      ##########   12.9   5.3   -2.3/ +7.6   *

   8/30/70  #####     4          3000      412.00    47.40     565      ##########    8.1   6.1    4.2/ +2.0   *
   8/30/70  #####    11          5460      570.00    25.40    1120      ##########   12.8   5.7   -1.4/ +7.1   *

   8/31/70  #####     4          3100      250.00   164.20     655      ##########    8.3   6.3    4.3/ +2.0   *
   8/31/70  #####    11          4100      680.00    42.30     830      ##########   12.8   5.8   -1.2/ +7.0   *

   9/ 2/70  #####     4          2520      298.00    94.80     415      ##########    8.3   6.4    4.5/ +1.9   *
   9/ 2/70  #####    11          4760      520.00   211.60     880      ##########   12.7   5.9   -1.0/ +6.8   *

   9/ 4/70  #####    11          3600      820.00     8.47     805      ##########   11.8   5.7   -0.4/ +6.1   *

   9/ 6/70  #####     4          2820      198.00    93.10     485      ##########    7.6   6.5    5.5/ +1.1   *
   9/ 6/70  #####    11          5100     1260.00    25.40    1040      ##########   11.3   5.4   -0.4/ +5.9   *

   9/ 7/70  #####     4          2560      190.00   118.50     475      ##########    7.6   6.5    5.5/ +1.1   *
   9/ 7/70  #####    11          3900      800.00    25.40     830      ##########   11.2   5.7    0.2/ +5.5   *

   9/ 8/70  #####     4          2840      196.00   176.10     565      ##########    7.8   6.5    5.1/ +1.3   *
   9/ 8/70  #####    11          5440     1250.00     8.50    1310      ##########   11.5   5.3   -0.8/ +6.2   *

   9/ 9/70  #####    11          6600     1750.00     8.50    1660      ##########   11.7   5.1   -1.5/ +6.6   *

   9/10/70  #####     4          1920      214.00   135.40     235      ##########    8.0   6.8    5.6/ +1.2   *
   9/10/70  #####    11          3300     1070.00    16.90    1050      ##########   12.0   5.5   -1.0/ +6.5   *

   9/11/70  #####     4          1400      254.00   142.20    1050      ##########    8.2   6.1    4.0/ +2.1   *
   9/11/70  #####    11          1620      650.00     8.50     845      ##########   12.1   5.8   -0.5/ +6.3   *

   9/12/70  #####     4          1410      252.00   140.50     200      ##########    8.2   6.8    5.4/ +1.4   *
   9/12/70  #####    11          3720      720.00    16.90     875      ##########   12.1   5.7   -0.6/ +6.4   *

   9/13/70  #####     4          2240      306.00   140.50     390      ##########    8.0   6.4    4.9/ +1.6   *
   9/13/70  #####    11          6160     1610.00     8.50    1670      ##########   12.3   5.1   -2.0/ +7.2   *

   9/14/70  #####     4          1980      254.00   147.30     335      ##########    7.8   6.6    5.4/ +1.2   *
   9/14/70  #####    11          4600      670.00    25.40     810      ##########   11.8   5.8   -0.2/ +6.0   *

   9/15/70  #####     4          1900      254.00   132.10     250      ##########    7.8   6.7    5.6/ +1.1   *
1908 9/15/70 #####   11          3500      690.00    59.30     850      ##########   11.7   5.8   -0.2/ +5.9   *
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DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
9/16/70	####	4	1580	202.00	140.50	375	#########	8.1	6.6	5.1/ +1.5
9/16/70	####	11	3300	1190.00	1.70	1015	#########	12.1	5.5	-1.2/ +6.6
9/18/70	####	11	1650	250.00	177.80	745	#########	11.5	6.2	1.0/ +5.3
9/19/70	####	11	1700	270.00	16.90	490	#########	11.2	6.4	1.5/ +4.8
9/20/70	####	11	3200	640.00	118.50	260	#########	11.5	6.3	1.1/ +5.2
9/21/70	####	4	1480	264.00	101.60	165	#########	7.9	6.9	5.8/ +1.0
9/21/70	####	5	356	120.00	118.50	115	#########	7.6	7.3	7.1/ +0.3
9/21/70	####	6	1676	250.00	177.80	200	#########	7.8	6.8	5.8/ +1.0
9/21/70	####	11	2300	550.00	143.90	710	#########	11.7	5.9	0.2/ +5.8
9/22/70	####	4	1740	248.00	111.70	330	#########	8.2	6.6	5.0/ +1.6
9/22/70	####	6	1740	256.00	111.70	375	#########	8.0	6.5	5.0/ +1.5
9/22/70	####	11	2570	940.00	16.90	865	#########	11.8	5.6	-0.5/ +6.2
9/23/70	####	4	1740	152.00	164.20	375	#########	8.3	6.7	5.1/ +1.6
9/23/70	####	6	1800	260.00	113.40	420	#########	8.2	6.5	4.7/ +1.7
9/23/70	####	11	3400	840.00	67.70	1040	#########	11.9	5.6	-0.7/ +6.3
9/24/70	####	11	3100	810.00	84.60	935	#########	11.9	5.7	-0.6/ +6.2
9/25/70	####	11	1354	490.00	25.40	310	#########	11.3	6.3	1.4/ +5.0
9/26/70	####	5	212	110.00	45.70	115	#########	8.0	7.4	6.7/ +0.6
9/26/70	####	6	1780	230.00	159.10	475	#########	8.0	6.5	4.9/ +1.5
9/26/70	####	11	1226	320.00	########	225	#########	11.1	####	#####/#####
9/27/70	####	4	1760	98.00	32.20	44	#########	8.2	7.8	7.4/ +0.4
9/27/70	####	11	916	150.00	5.00	280	#########	10.4	6.8	3.3/ +3.6
9/29/70	####	4	3360	168.00	193.90	240	#########	10.7	6.9	3.1/ +3.8
9/29/70	####	5	1620	96.00	23.70	85	#########	7.1	7.5	8.0/ -0.4
9/29/70	####	11	400	84.00	52.50	150	#########	8.6	7.4	6.1/ +1.2
9/30/70	####	4	2800	160.00	196.40	550	#########	8.0	6.5	5.0/ +1.5
9/30/70	####	11	400	84.00	52.50	150	#########	8.6	7.4	6.1/ +1.2
9/30/70	####	11	1400	410.00	12.70	15	#########	9.3	7.7	6.1/ +1.6
10/ 2/70	####	4	2280	264.00	115.00	530	#########	7.8	6.4	4.9/ +1.4
10/ 3/70	####	11	1440	80.00	67.50	140	#########	8.4	7.4	6.4/ +1.0
10/ 4/70	####	4	2220	196.00	20.30	320	#########	7.3	6.7	6.1/ +0.6
10/ 4/70	####	11	1360	50.00	93.00	125	#########	8.2	7.7	7.1/ +0.5
10/ 5/70	####	4	2240	168.00	294.60	135	#########	8.7	7.2	5.6/ +1.5
10/ 5/70	####	11	1800	80.00	215.00	380	#########	9.6	7.0	4.4/ +2.6

842

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	1/IS
10/ 6/70	#####	4	1840	130.00	174.40	250	#########	7.6	7.0	6.3/ +0.7
10/ 6/70	#####	11	1600	50.00	118.50	140	#########	8.6	7.6	6.7/ +1.0
10/ 7/70	#####	4	2340	222.00	133.70	400	#########	7.8	6.6	5.3/ +1.2
10/ 7/70	#####	11	1380	60.00	118.00	95	#########	8.5	7.7	6.9/ +0.8
10/ 8/70	#####	4	410	92.00	3.40	130	#########	7.7	7.4	7.0/ +0.3
10/ 8/70	#####	5	410	92.00	5	130	#########	7.7	7.4	7.0/ +0.3 #
10/ 8/70	#####	11	1070	70.00	76.20	75	#########	8.3	7.7	7.2/ +0.6
10/ 9/70	#####	4	1680	138.00	203.20	325	#########	7.8	6.9	5.9/ +0.9
10/ 9/70	#####	11	720	70.00	152.40	70	#########	8.1	7.8	7.5/ +0.3
10/10/70	#####	4	1500	172.00	199.80	180	#########	7.7	7.0	6.3/ +0.7
10/10/70	#####	11	980	100.00	135.40	115	#########	8.2	7.4	6.7/ +0.8
10/11/70	#####	4	3160	186.00	62.60	480	#########	7.9	6.5	5.2/ +1.4
10/11/70	#####	11	1640	90.00	169.00	185	#########	8.2	7.3	6.4/ +0.8
10/12/70	#####	4	2760	164.00	33.90	300	#########	7.8	6.8	5.8/ +1.0
10/12/70	#####	11	550	80.00	939.00	140	#########	8.5	7.5	6.5/ +1.0
10/13/70	#####	4	3200	214.00	220.00	495	#########	7.9	6.5	5.1/ +1.4
10/13/70	#####	11	1320	220.00	16.90	130	#########	10.3	7.0	3.7/ +3.3
10/14/70	#####	4	2640	160.00	42.30	650	#########	7.9	6.5	5.0/ +1.4
10/14/70	#####	11	738	90.00	110.00	135	#########	7.8	7.4	7.0/ +0.4
10/15/70	#####	4	2180	186.00	172.70	630	#########	8.3	6.4	4.6/ +1.9
10/15/70	#####	11	1430	120.00	152.40	265	#########	8.1	7.0	5.9/ +1.1
10/16/70	#####	4	1720	192.00	198.30	660	#########	8.2	6.4	4.6/ +1.8
10/16/70	#####	11	1520	90.00	194.70	465	#########	8.3	6.9	5.5/ +1.4
10/17/70	#####	11	1320	120.00	160.80	455	#########	8.5	6.8	5:0/ +1.7
10/18/70	#####	4	2400	284.00	206.50	890	#########	8.4	6.1	3.8/ +2.3
10/18/70	#####	11	1680	100.00	347.10	755	#########	8.7	6.6	4.6/ +2.1
10/19/70	#####	11	1900	160.00	203.20	800	#########	9.2	6.4	3.6/ +2.8
10/20/70	#####	4	2840	328.00	192.80	885	#########	8.3	6.1	3.8/ +2.2
10/20/70	#####	11	3460	200.00	262.40	1020	#########	9.1	6.2	3.3/ +2.9
10/21/70	#####	4	4660	372.00	147.30	1035	#########	8.6	5.9	3.3/ +2.7
10/21/70	#####	11	3400	160.00	355.50	1020	#########	9.2	6.3	3.4/ +2.9
10/22/70	#####	4	1100	196.00	54.20	460	#########	8.3	6.5	4.8/ +1.8
10/22/70	#####	11	2840	60.00	211.00	715	#########	9.5	6.9	4.2/ +2.6

925

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
10/25/70	****	4	2520	398.00	11.80	805	*********	8.3	6.0	3.7/ +2.3
10/25/70	****	11	2000	100.00	270.00	800	*********	8.8	6.6	4.4/ +2.2
10/26/70	****	4	2640	256.00	169.00	980	*********	8.2	6.1	4.0/ +2.1
10/26/70	****	11	1680	60.00	212.00	645	*********	9.2	6.9	4.6/ +2.3
10/27/70	****	4	4040	448.00	32.20	1135	*********	8.4	5.8	3.2/ +2.6
10/27/70	****	11	3400	160.00	253.90	920	*********	9.1	6.3	3.6/ +2.8
10/28/70	****	4	3140	284.00	154.00	1000	*********	8.3	6.1	3.8/ +2.2
10/28/70	****	11	2560	320.00	262.00	1105	*********	9.0	6.0	3.0/ +3.0
10/29/70	****	4	3040	250.00	167.00	1150	*********	8.2	6.0	3.8/ +2.2
10/29/70	****	11	2500	160.00	321.00	1040	*********	9.0	6.3	3.6/ +2.7
10/30/70	****	4	3660	40.00	447.00	1090	*********	8.7	6.9	5.1/ +1.8
10/30/70	****	11	2800	40.00	389.00	940	*********	9.0	6.9	4.9/ +2.1
10/31/70	****	4	3440	212.00	271.00	1335	*********	8.7	6.1	3.4/ +2.6
10/31/70	****	11	2360	50.00	322.00	965	*********	8.9	6.8	4.8/ +2.1
11/ 1/70	****	3	*********	********	********	*********	*********	****	****	*****/ 0.0
11/ 1/70	****	4	3000	96.00	342.00	745	*********	7.9	6.7	5.6/ +1.2
11/ 1/70	****	11	2280	90.00	245.00	735	*********	8.3	6.7	5.1/ +1.6
11/ 2/70	****	3	*********	********	********	*********	*********	****	****	*****/ 0.0
11/ 2/70	****	4	5260	40.00	545.00	1390	*********	8.6	6.8	5.2/ +1.8
11/ 2/70	****	11	2380	40.00	270.00	625	*********	9.0	7.1	5.2/ +1.9
11/ 3/70	****	3	*********	********	********	*********	*********	****	****	*****/ 0.0
11/ 3/70	****	4	6400	468.00	52.00	1765	*********	8.7	5.4	2.2/ +3.3
11/ 3/70	****	11	2720	190.00	330.00	980	*********	9.2	6.3	3.3/ +2.9
11/ 4/70	****	3	*********	********	********	*********	*********	****	****	*****/ 0.0
11/ 4/70	****	4	*********	********	********	*********	*********	****	****	*****/ 0.0
11/ 4/70	****	11	2240	50.00	466.00	1285	*********	9.2	6.7	4.2/ +2.5
11/ 5/70	****	3	*********	********	********	*********	*********	****	****	*****/ 0.0
11/ 5/70	****	4	4950	262.00	630.00	450	*********	7.8	6.5	5.3/ +1.3
11/ 5/70	****	11	2360	120.00	609.00	320	*********	8.2	7.0	5.7/ +1.2
11/ 6/70	****	3	*********	********	********	*********	*********	****	****	*****/ 0.0
11/ 6/70	****	4	4340	44.00	733.00	1930	*********	7.7	6.6	5.8/ +1.1
11/ 6/70	****	11	3400	40.00	660.00	1540	*********	8.1	6.8	5.4/ +1.3
11/ 7/70	****	3	*********	********	********	*********	*********	****	****	*****/ 0.0
11/ 7/70	****	4	3150	58.00	572.00	1230	*********	7.5	6.7	6.1/ +0.8
11/ 7/70	****	11	2720	40.00	406.00	1155	*********	8.1	6.9	5.6/ +1.2
11/ 8/70	****	3	*********	********	********	*********	*********	****	****	*****/ 0.0

1010

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  DATE     TIME   LOCATION  CONDUCTIVITY    CACO3     MGCO3   ALKALINITY   SUSP.SOLIDS    PH   PHS       I/IS

11/ 8/70   ####      3        #########    ########  ########  ########     #########    ####  ####  #####/  0.0
11/ 8/70   ####      4             5380       74.00    597.70      1173     #########     9.6   6.6    4.8/ +2.0
11/ 8/70   ####     11             3400       30.00    435.10       570     #########     9.0   7.3    5.6/ +1.7

11/ 9/70   ####      3        #########    ########  ########  ########     #########    ####  ####  #####/  0.0
11/ 9/70   ####      4             4700      100.00    594.20      1555     #########     8.5   6.3    4.4/ +2.2
11/ 9/70   ####     11             4400      150.00    514.70       585     #########     8.2   6.6    5.0/ +1.6

11/10/70   ####      3        #########    ########  ########  ########     #########    ####  ####  #####/  0.0
11/10/70   ####      4             5200       60.00    641.60      1710     #########     8.4   6.5    4.9/ +1.8
11/10/70   ####     11             3600       33.40    436.80       155     #########     7.5   7.8    8.1/ -0.3

11/11/70   ####      4             6000     1034.00     39.00      2430     #########     8.7   5.1    1.6/ +3.6
11/11/70   ####      4             1600       64.00    645.00      1510     #########     8.6   6.6    4.6/ +2.0
11/11/70   ####     11             1070      116.00    619.60       490     #########     7.4   6.8    6.2/ +0.6

11/12/70   ####      4             6150       92.00    804.00      1920     #########     7.6   6.3    5.0/ +1.3
11/12/70   ####     11             5920       92.00    747.00       630     #########     6.1   6.8    7.5/ -0.7

11/14/70   ####      3        #########    ########  ########  ########     #########    ####  ####  #####/  0.0
11/14/70   ####      4        #########    ########  ########  ########     #########    ####  ####  #####/  0.0

11/15/70   ####      3        #########    ########  ########  ########     #########    ####  ####  #####/  0.0
11/15/70   ####      4        #########    ########  ########  ########     #########    ####  ####  #####/  0.0

11/16/70   ####      3        #########    ########  ########  ########     #########    ####  ####  #####/  0.0
11/16/70   ####      4             5960      508.00    438.00      1340     #########     8.6   5.7    3.9/ +2.9
11/16/70   ####     11             4440      312.00    362.00       890     #########     8.6   6.1    3.6/ +2.5

11/17/70   ####      3        #########    ########  ########  ########     #########    ####  ####  #####/  0.0
11/17/70   ####      4             5660      360.00    466.00      2045     #########     8.8   5.7    2.7/ +3.1
11/17/70   ####     11             5740       29.60    460.00      1455     #########     8.9   6.9    4.9/ +2.0

11/18/70   ####      3        #########    ########  ########  ########     #########    ####  ####  #####/  0.0
11/18/70   ####      4             7050      120.00    609.00       103     #########     8.8   7.4    6.2/ +1.4
11/18/70   ####     11             4000      130.00  ########      1270     #########     9.0  ####  #####/#####

11/19/70   ####      3        #########    ########  ########  ########     #########    ####  ####  #####/  0.0
11/19/70   ####      4             5150      156.00  ########      1640     #########     8.6  ####  #####/#####
11/19/70   ####     11             3400      100.00    303.00       915     #########     8.7   6.6    4.4/ +2.1

11/20/70   ####      3        #########    ########  ########  ########     #########    ####  ####  #####/  0.0
11/20/70   ####      4             6000      152.00    477.00      2050     #########     8.4   6.0    3.8/ +2.4
11/20/70   ####     11             3950      140.00    367.00      1260     #########     8.7   6.3    3.9/ +2.4

11/21/70   ####      3        #########    ########  ########  ########     #########    ####  ####  #####/  0.0
11/21/70   ####      4             5900       66.00    645.00      1690     #########     8.4   6.5    4.8/ +1.9

11/22/70   ####      3        #########    ########  ########  ########     #########    ####  ####  #####/  0.0
11/22/70   ####      4             5580      188.00    394.40      1680     #########     8.5   6.0    3.7/ +2.5
947
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DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
11/23/70	****	3	********	********	********	********	********	****	****	*****/ 0.0
11/23/70	****	4	5300	104.00	27.10	1960	********	8.4	6.1	4.0/ +2.3
11/23/70	****	11	3960	16.00	430.00	1550	********	8.9	7.1	5.4/ +1.8
11/24/70	****	3	********	********	********	********	********	****	****	*****/ 0.0
11/24/70	****	4	5350	192.00	335.20	810	********	8.4	6.3	4.3/ +2.1
11/24/70	****	11	4120	140.00	272.60	1245	********	9.0	6.3	3.5/ +2.7
11/25/70	****	3	********	********	********	********	********	****	****	*****/ 0.0
11/25/70	****	4	4300	508.00	438.40	1560	********	8.7	5.6	2.7/ +3.1
11/25/70	****	11	3100	312.00	362.30	805	********	9.4	6.1	2.9/ +3.3
11/26/70	****	3	********	********	********	********	********	****	****	*****/ 0.0
11/26/70	****	4	800	20.00	569.80	1790	********	8.4	6.4	4.5/ +2.0
11/26/70	****	11	1260	24.00	314.00	1010	********	9.[illegible]	7.1	5.3/ +1.9
11/27/70	****	3	********	********	********	********	********	****	****	*****/ 0.0
11/27/70	****	4	5500	264.00	345.40	1545	********	8.5	5.9	3.5/ +2.6
11/27/70	****	11	4650	152.00	324.90	1425	********	9.0	6.2	3.4/ +2.8
11/27/70	****	11	3580	168.00	287.80	545	********	9.0	6.6	4.1/ +2.4
11/28/70	****	3	********	********	********	********	********	****	****	*****/ 0.0
11/28/70	****	4	4600	22.00	611.00	1655	********	8.1	7.0	6.0/ +1.1
11/28/70	****	11	3450	6.00	107.00	795	********	8.9	7.8	6.7/ +1.1
11/29/70	****	3	********	********	********	********	********	****	****	*****/ 0.0
11/29/70	****	4	********	********	********	********	********	****	****	*****/ 0.0
11/30/70	****	3	********	********	********	********	********	****	****	*****/ 0.0
11/30/70	****	4	4900	16.00	32.80	1795	********	8.5	7.0	5.6/ +1.5
11/30/70	****	11	3250	14.00	69.40	675	********	9.0	7.5	5.9/ +1.5
12/ 1/70	****	3	********	********	********	********	********	****	****	*****/ 0.0
12/ 1/70	****	4	5550	32.00	698.00	2195	********	8.5	6.7	5.1/ +1.8
12/ 1/70	****	11	3400	16.00	187.90	790	********	9.0	7.3	5.7/ +1.7
12/ 2/70	****	3	********	********	********	********	********	****	****	*****/ 0.0
12/ 2/70	****	4	5950	260.00	********	2090	********	8.6	****	*****/*****
12/ 2/70	****	11	2920	64.00	1090.80	845	********	9.3	6.8	4.4/ +2.5
12/ 3/70	****	3	********	********	********	********	********	****	****	*****/ 0.0
12/ 3/70	****	4	5600	500.00	252.20	1950	********	8.5	5.5	2.7/ +3.0
12/ 3/70	****	11	2640	158.00	1557.50	750	********	8.8	6.5	4.2/ +2.3
12/ 4/70	****	3	********	********	********	********	********	****	****	*****/ 0.0
12/ 4/70	****	4	3950	12.00	431.70	1445	********	8.9	7.3	5.8/ +1.6
12/ 4/70	****	11	2350	80.00	1523.70	520	********	8.4	6.9	5.5/ +1.5
12/ 5/70	****	4	3920	314.00	279.30	1460	********	8.5	5.9	3.2/ +2.6

1034

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  DATE     TIME  LOCATION  CONDUCTIVITY   CACO3    MGCO3  ALKALINITY  SUSP.SOLIDS   PH   PHS       I/IS
 12/ 5/70  *****    11          1680     108.00    59.20     395      *********    9.4   6.8   4.3/ +2.6

 12/ 6/70  *****     4          4900     196.00   490.00    1750      *********    8.5   6.0   3.5/ +2.5
 12/ 6/70  *****    11          2680      96.00   287.50      67      *********    9.0   7.7   6.4/ +1.3

 12/ 7/70  *****     4          3660     186.00   333.50    1160      *********    8.4   6.2   4.0/ +2.2
 12/ 7/70  *****    11          2140     116.00   231.90     615      *********    8.7   6.7   4.6/ +2.0

 12/ 8/70  *****     3     *********   ********* ********* *********  *********  ***** ***** ******/ 0.0
 12/ 8/70  *****     4          3320      50.00   358.00    1025      *********    8.4   6.8   5.3/ +1.6
 12/ 8/70  *****    11          2680       2.60   382.60     845      *********    9.0   8.2   7.3/ +0.8

 12/ 9/70  *****     4          3400     180.00   321.60    1035      *********    8.5   6.3   4.0/ +2.2
 12/ 9/70  *****    11          3000      40.00   306.40     760      *********    9.3   7.0   4.8/ +2.3

 12/10/70  *****     3     *********   ********* ********* *********  *********  ***** ***** ******/ 0.0
 12/10/70  *****     4          3250     140.00   338.60     910      *********    8.7   6.4   4.2/ +2.3
 12/10/70  *****    11          2280      40.00   336.90    5250      *********    9.3   6.2   3.1/ +3.1

 12/11/70  *****     3     *********   ********* ********* *********  *********  ***** ***** ******/ 0.0
 12/11/70  *****     4          3400      40.00   414.70     925      *********    8.4   7.0   5.7/ +1.4
 12/11/70  *****    11          2900      32.00   406.30     855      *********    9.3   7.1   4.9/ +2.2

 12/12/70  *****     3     *********   ********* ********* *********  *********  ***** ***** ******/ 0.0
 12/12/70  *****     4          3250     290.00   194.60     120      *********    8.4   6.9   5.6/ +1.5
 12/12/70  *****    11          2500     158.00   138.80     760      *********    9.2   6.4   3.6/ +2.8

 12/13/70  *****     3     *********   ********* ********* *********  *********  ***** ***** ******/ 0.0
 12/13/70  *****     4          5800     128.00    60.80     105      *********    7.8   7.3   7.6/ +0.5
 12/13/70  *****    11          2000     240.00   237.00     705      *********    9.0   6.3   3.6/ +2.7

 12/14/70  *****     3     *********   ********* ********* *********  *********  ***** ***** ******/ 0.0
 12/14/70  *****     4          3380     590.00   624.80    1025      *********    8.5   5.8   3.2/ +2.7
 12/14/70  *****    11          2290     200.00   228.50     675      *********    9.0   6.4   3.8/ +2.6

 12/15/70  *****     3     *********   ********* ********* *********  *********  ***** ***** ******/ 0.0
 12/15/70  *****     4          3100      40.00   254.00     990      *********    8.6   6.9   5.3/ +1.7
 12/15/70  *****    11          1760      20.00    84.70     330      *********    9.5   7.6   5.8/ +1.9

 12/16/70  *****     3     *********   ********* ********* *********  *********  ***** ***** ******/ 0.0
 12/16/70  *****     4          2520      34.00   248.00     785      *********    8.4   7.1   5.9/ +1.3
 12/16/70  *****    11          1670      40.00    16.90     200      *********   10.0   7.5   5.0/ +2.5

 12/17/70  *****     3     *********   ********* ********* *********  *********  ***** ***** ******/ 0.0
 12/17/70  *****     4          2760      60.00   287.80     800      *********    8.4   6.8   5.4/ +1.6
 12/17/70  *****    11          1860      46.00    71.10     320      *********    9.3   7.3   5.3/ +2.0

 12/18/70  *****     3     *********   ********* ********* *********  *********  ***** ***** ******/ 0.0
 12/18/70  *****     4          2640      40.00   279.30     560      *********    8.4   7.1   5.8/ +1.3
 12/18/70  *****    11          2040      80.00   226.80     355      *********    8.5   7.1   5.6/ +1.4
1121
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DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	1/IS
12/19/70	####	3	#########	########	########	########	########	####	####	#####/ 0.0
12/19/70	####	4	#########	########	########	########	########	####	####	#####/ 0.0
12/19/70	####	11	2600	50.00	291.10	900	########	8.4	6.9	5.3/ +1.5
12/19/70	####	11	2200	200.00	253.90	680	########	8.7	6.4	4.1/ +2.3
12/20/70	####	3	#########	########	########	########	########	####	####	#####/ 0.0
12/20/70	####	4	2380	70.00	225.10	565	########	8.1	6.9	5.9/ +1.2
12/20/70	####	11	1150	120.00	8.40	65	########	10.0	7.6	5.1/ +2.4
12/21/70	####	3	#########	########	########	########	########	####	####	#####/ 0.0
12/21/70	####	4	#########	########	########	########	########	####	####	#####/ 0.0
12/21/70	####	11	2440	156.00	28.70	65	########	10.0	7.5	4.9/ +2.5
12/22/70	####	3	#########	########	########	########	########	####	####	#####/ 0.0
12/22/70	####	4	2680	3.60	1.70	38	########	9.1	3.8	9.7/ 0.7
12/22/70	####	11	1620	198.00	4.90	75	########	10.5	7.3	4.0/ +3.2
12/23/70	####	3	#########	########	########	########	########	####	####	#####/ 0.0
12/23/70	####	4	#########	########	########	########	########	####	####	#####/ 0.0
12/23/70	####	11	1520	50.00	347.00	325	########	9.0	7.3	5.6/ +1.7
12/24/70	####	3	#########	########	########	########	########	####	####	#####/ 0.0
12/24/70	####	4	3200	108.00	352.10	655	########	8.3	6.7	5.2/ +1.6
12/24/70	####	11	1880	60.00	176.90	150	########	9.1	7.5	6.0/ +1.6
12/25/70	####	3	#########	########	########	########	########	####	####	#####/ 0.0
12/25/70	####	4	3000	104.00	306.00	585	########	8.2	6.7	5.8/ +1.5
12/25/70	####	11	1780	44.00	200.00	240	########	8.4	7.5	6.5/ +0.9
12/26/70	####	3	#########	########	########	########	########	####	####	#####/ 0.0
12/26/70	####	4	3000	100.00	274.00	600	########	8.4	6.7	5.2/ +1.7
12/26/70	####	11	2020	40.00	237.00	300	########	8.9	7.4	5.9/ +1.5
12/27/70	####	3	#########	########	########	########	########	####	####	#####/ 0.0
12/27/70	####	4	2560	130.00	33.90	595	########	7.8	6.6	5.5/ +1.2
12/27/70	####	11	1170	100.00	16.90	40	########	9.0	7.8	6.7/ +1.2
12/28/70	####	3	#########	########	########	########	########	####	####	#####/ 0.0
12/28/70	####	4	2540	136.00	162.50	480	########	7.8	6.7	5.7/ +1.1
12/28/70	####	11	1210	90.00	15.20	50	########	8.8	7.8	6.8/ +1.0
12/29/70	####	3	#########	########	########	########	########	####	####	#####/ 0.0
12/29/70	####	4	2520	134.00	99.90	580	########	7.9	6.6	5.4/ +1.3
12/29/70	####	11	1180	220.00	37.20	45	########	8.9	7.5	6.1/ +1.4
12/31/70	####	3	#########	########	########	########	########	####	####	#####/ 0.0
12/31/70	####	4	#########	########	########	########	########	####	####	#####/ 0.0
4/ 3/71	800	4	2984	284.00	205.00	600	########	7.9	6.3	4.7/ +1.6
1208										

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS	•
4/ 3/71	800	4	2984	284.00	205.00	600	*********	7.9	6.3	4.7/ +1.6	*
4/ 4/71	800	4	3100	408.00	249.00	340	*********	7.9	6.4	4.9/ +1.5	*
4/ 6/71	800	4	3400	398.00	349.00	325	*********	10.1	6.4	2.8/ +3.7	*
4/ 7/71	900	4	3900	336.00	157.00	470	*********	7.7	6.3	4.9/ +1.4	*
4/ 7/71	940	4	3900	248.00	222.00	460	*********	7.6	6.5	5.3/ +1.1	*
4/ 7/71	1000	4	4120	334.00	156.00	420	*********	7.7	6.4	5.0/ +1.3	*
4/ 7/71	1130	3	4320	412.00	139.00	410	*********	7.6	6.3	5.0/ +1.3	*
4/ 7/71	1400	4	4680	390.00	137.00	395	*********	7.4	6.3	5.3/ +1.1	*
4/ 8/71	800	4	4800	********	********	********	*********	8.1	****	*****/*****	*
4/ 9/71	800	4	4800	********	********	********	*********	8.1	****	*****/*****	*
4/10/71	800	4	3900	********	********	********	*********	8.0	****	*****/*****	*
4/11/71	800	4	3800	194.00	283.00	645	*********	8.7	6.4	4.1/ +2.3	*
4/12/71	800	4	5200	318.00	332.00	425	*********	8.0	6.4	4.8/ +1.6	>
4/13/71	800	4	5800	570.00	151.00	575	*********	8.3	6.0	3.7/ +2.3	*
4/14/71	800	4	5450	540.00	159.00	550	*********	7.9	6.1	4.2/ +1.8	*
4/15/71	800	4	5000	360.00	415.00	175	*********	7.7	6.7	5.8/ +1.0	*
4/16/71	800	4	4500	********	********	275	*********	8.0	****	*****/*****	*
4/19/71	800	4	*********	390.00	93.00	120	*********	****	****	*****/ 0.0	*
4/20/71	800	4	4800	410.00	42.00	470	*********	8.2	6.2	4.3/ +2.0	>
4/21/71	800	4	4700	350.00	94.00	675	*********	8.7	6.1	3.6/ +2.6	>
4/22/71	800	4	5340	232.00	108.00	1160	*********	8.8	6.1	3.3/ +2.7	>
4/23/71	800	4	6700	230.00	76.00	1085	*********	8.9	6.1	3.3/ +2.8	>
4/26/71	800	4	4600	210.00	127.00	550	*********	8.2	6.4	4.7/ +1.8	>
4/27/71	800	4	3800	300.00	127.00	1170	*********	8.8	6.0	3.1/ +2.8	>
4/28/71	800	4	4900	360.00	195.00	1400	*********	8.0	5.8	3.6/ +2.2	>
4/29/71	800	4	4900	390.00	157.00	840	*********	8.2	6.0	3.8/ +2.2	>
4/29/71	945	4	5850	344.00	183.00	955	*********	8.0	6.0	4.0/ +2.0	>
4/29/71	1400	4	*********	********	********	********	*********	7.8	****	*****/*****	>
4/30/71	800	4	4320	450.00	169.00	550	*********	8.0	6.1	4.3/ +1.9	>

1085

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
5/ 1/71	800	4	4460	416.00	225.00	415	*********	7.8	6.3	4.8/ +1.5
5/ 2/71	800	4	4660	344.00	190.00	510	*********	7.9	6.3	4.7/ +1.6
5/ 3/71	800	4	4800	168.00	437.00	600	*********	8.6	6.5	4.5/ +2.1
5/ 4/71	800	4	5000	330.00	322.00	575	*********	8.2	6.3	4.3/ +1.9
5/ 5/71	800	4	4800	356.00	223.00	595	*********	8.1	6.2	4.3/ +1.9
5/ 6/71	800	4	5000	272.00	312.00	625	*********	7.9	6.3	4.7/ +1.6
5/ 7/71	800	4	4000	340.00	207.00	245	*********	8.4	6.6	4.8/ +1.8
5/10/71	800	4	4800	240.00	305.00	250	*********	7.7	6.7	5.8/ +1.0
5/11/71	800	4	5360	400.00	105.00	800	*********	8.0	6.0	4.0/ +2.0
5/12/71	800	4	4300	80.00	305.00	790	*********	8.2	6.7	5.2/ +1.5
5/13/71	800	4	3800	306.00	107.00	750	*********	8.1	6.1	4.2/ +2.0
5/14/71	800	4	4350	306.00	174.00	560	*********	8.3	6.3	4.3/ +2.0
5/15/71	800	4	1500	150.00	208.00	645	*********	8.3	6.5	4.7/ +1.8
5/16/71	800	4	2360	136.00	227.00	665	*********	8.1	6.6	5.0/ +1.5
5/17/71	800	4	3400	300.00	179.00	710	*********	8.1	6.2	4.3/ +1.9
5/18/71	800	4	4100	270.00	244.00	1125	*********	8.5	6.0	3.6/ +2.5
5/19/71	800	4	4000	302.00	185.00	150	*********	7.0	6.8	6.5/ +0.2
5/20/71	800	4	3800	380.00	174.00	170	*********	7.2	6.7	6.2/ +0.5
5/21/71	800	4	4560	508.00	358.00	25	*********	6.9	7.4	8.0/ -0.5
5/22/71	800	4	3880	434.00	273.00	235	*********	7.4	6.5	5.7/ +0.9
5/23/71	800	4	4040	434.00	259.00	545	*********	8.2	6.2	4.1/ +2.0
5/24/71	800	4	2240	280.00	117.00	510	*********	8.3	6.4	4.4/ +1.9
5/25/71	800	4	4350	302.00	185.00	625	*********	8.4	6.2	4.1/ +2.2
5/26/71	800	4	3900	338.00	120.00	640	*********	8.3	6.2	4.1/ +2.1
5/27/71	800	4	5100	50.00	584.00	115	*********	8.2	7.8	7.4/ +0.4

1160

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 DATE     TIME  LOCATION  CONDUCTIVITY   CACO3    MGCO3   ALKALINITY  SUSP.SOLIDS   PH   PHS      I/IS
5/28/71   800      4           2740     394.00   164.00        390     *********   8.1   6.3   4.6/ +1.8
5/30/71   800      4      *********   ********  ********  ********     *********   7.3  ****  *****/*****
5/31/71   800      4      *********   ********  ********  ********     *********   7.1  ****  *****/*****
6/ 1/71   800      4           3200     540.00   371.00   ********     *********   6.7  ****  *****/*****
6/ 2/71   800      4           4120     490.00   195.00        245     *********   7.5   6.5   5.4/ +1.0
6/ 3/71   800      4           4420     504.00   381.00        430     *********   7.9   6.2   4.5/ +1.7
6/ 4/71   800      4           3400     128.00   538.00        535     *********   8.3   6.7   5.1/ +1.6
6/ 5/71   800      4           4100   ********  ********  ********     *********   8.1  ****  *****/*****
6/ 6/71   800      4      *********   ********  ********  ********     *********   8.4  ****  *****/*****
6/ 7/71   800      4           4250     558.00   217.00        270     *********   8.0   6.4   4.7/ +1.6
5/ 8/71   800      4           3580     324.00   317.00        300     *********   8.2   6.5   4.9/ +1.7
6/ 9/71   800      4           3900     320.00   239.00        645     *********   8.5   6.2   3.9/ +2.3
6/10/71   800      4           4480     104.00   476.00        690     *********   8.3   6.7   5.1/ +1.6
6/11/71   800      4           4820     378.00   340.00        595     *********   8.2   6.2   4.2/ +2.0
6/12/71   800      4      *********     290.00   379.00        570     *********   8.4   6.3   4.2/ +2.1
6/13/71   800      4      *********     206.00   491.00        525     *********   8.6   6.5   4.4/ +2.1
6/14/71   900      4      *********     558.00   467.00        585     *********   8.4   6.0   3.7/ +2.4
6/15/71   800      4      *********      50.00   904.00        900     *********   8.3   6.9   5.5/ +1.4
6/16/71   800      4           6000     276.00   543.00        840     *********   8.2   6.2   4.2/ +2.0
6/17/71   800      4           6050     474.00   306.00        740     *********   8.2   6.0   3.8/ +2.2
6/18/71   800      4           6640     422.00   254.00        960     *********   8.2   5.9   3.6/ +2.3
6/19/71   800      4           2200   ********  ********  ********     *********   8.4  ****  *****/*****
6/20/71   800      4           5000   ********  ********  ********     *********   8.4  ****  *****/*****
6/21/71   800      4      *********    1100.00   407.00       1360     *********   7.9   5.4   2.9/ +2.5
6/22/71   800      4          10200    1203.00   111.00        875     *********   8.5   5.5   2.6/ +3.0
6/23/71   800      4            200     299.00    19.00        205     *********   8.5   6.7   4.9/ +1.8
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1130

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
6/24/71	800	4	2460	251.00	56.00	470	********	8.5	6.4	4.3/ +2.1
6/26/71	800	4	4200	515.00	60.00	920	********	8.1	5.8	3.6/ +2.3
6/27/71	800	4	3600	*******	*******	********	********	7.6	****	*****/*****
6/28/71	800	4	4280	560.00	60.00	********	********	8.4	****	*****/*****
6/29/71	800	4	3240	788.00	164.00	800	********	8.3	5.7	3.2/ +2.6
6/30/71	800	4	5300	804.00	46.00	585	********	8.6	5.9	3.1/ +2.7
7/ 1/71	800	4	5420	921.00	58.00	425	********	8.3	5.9	3.6/ +2.4
7/ 2/71	800	4	5038	879.00	*******	580	********	8.3	****	*****/*****
7/ 4/71	800	4	2130	190.00	51.00	25	********	9.9	7.8	5.7/ +2.1
7/ 7/71	800	4	7200	668.00	60.00	700	********	8.4	5.9	3.3/ +2.5
7/ 9/71	800	4	4000	473.00	34.00	365	********	8.8	6.3	3.8/ +2.5
7/10/71	800	4	2820	1394.00	*******	1095	********	8.2	****	*****/*****
7/12/71	800	4	3300	325.00	127.00	415	********	9.8	6.4	4.0/ +2.4
7/13/71	800	4	3380	105.00	311.00	315	********	8.6	7.0	5.4/ +1.6
7/14/71	800	4	3400	263.00	157.00	320	********	9.1	6.6	4.1/ +2.5
7/15/71	800	4	2650	303.00	150.00	410	********	9.1	6.4	3.7/ +2.7
7/16/71	800	4	4580	83.00	371.00	590	********	9.0	6.8	4.7/ +2.2
7/17/71	800	4	3420	*******	*******	540	********	8.7	****	*****/*****
7/19/71	800	4	3850	246.00	422.00	485	********	8.5	6.5	4.4/ +2.0
7/20/71	800	4	3800	81.00	563.00	495	********	8.6	6.9	5.3/ +1.7
7/21/71	800	4	4050	67.00	532.00	375	********	9.0	7.1	5.3/ +1.9
7/22/71	800	4	6300	141.00	327.00	635	********	8.6	6.6	4.5/ +2.0
7/23/71	800	4	6000	95.00	467.00	650	********	8.9	6.7	4.6/ +2.2
7/24/71	800	4	********	*******	*******	********	********	8.4	****	*****/*****
7/26/71	800	4	3040	99.00	345.00	245	********	8.5	7.1	5.8/ +1.4

1211

DATE	TIME	LOCATION	CONDUCTIVITY	CACO3	MGCO3	ALKALINITY	SUSP.SOLIDS	PH	PHS	I/IS
7/27/71	800	4	4050	145.00	426.00	535	*********	****	****	*****/ 0.0
7/28/71	800	4	2880	40.00	291.00	395	*********	9.2	7.3	5.4/ +1.9
6/25/71	800	4	3480	368.00	68.00	590	*********	8.6	6.2	3.7/ +2.4
5/20/71	800	4	2680	424.00	318.00	425	*********	6.4	6.3	6.2/ +0.1
4/ 5/71	800	4	3800	460.00	51.00	500	*********	9.1	6.2	3.2/ +2.9

APPENDIX F

MODIFICATIONS OF THE RECIRCULATION SYSTEM

Since preparation of the preceding final report in 1972, minor changes have been made to provide a system which is easier to control and maintain. These changes are described and explained below.

Vacuum for Sludge Filters

During the early operation of the recirculation system, reciprocating vacuum pumps were used to develop the required suction at the secondary clarifier sludge filters. Due to the high incidence of failure and excessive maintenance requirements, the pumps have been replaced by steam ejectors. These units have provided satisfactory service.

Control of Solids Build-up in The Recycle System

About a year ago, the blast furnace gas systems began to experience high pressure drops through the counter-current spray towers or gas coolers. High back-pressure was found to be the result of suspended solids plugging the openings in banks of ceramic drip tile within the gas coolers. In order to reduce the high-pressure drops, the gas coolers were acid cleaned every week or two. Use of a corrosion inhibitor was considered, but the benefits were doubtful and the cost would have been excessive.

Several water treatment companies were asked to analyze the problem and recommend a procedure or chemical treatment which would prevent clogging of the tile banks. The procedure which has been in use during the past six months was developed by Calgon Company. It involves the addition of a chemical named Calgon CL-134. During the six months that this chemical has been used, there has been no evidence of plugging in the coolers; in fact, there has been a gradual decrease in the pressure drop through these units.

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We are presently in the final stages of installation of a chemical addition system designed to control pH and suspended solids in the recycle system. We will add acid and Calgon CL-134 in controlled quantities. The initial cost of this additional chemical control system will be about $56,000.

Secondary Clarifier Cooling Tower

As is stated on page 82 of this report, the installation of a cooling tower at the sinter plant recycle system was not required. The circulation of high pH water through the cooling tower has resulted in attack on the tower structure which finally caused it to deteriorate to the extent that it was unusable. The cooling tower has therefore been by-passed with no noticeable undesirable effects.